AgRISTARS

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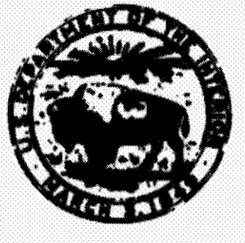
A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

Inventory Technology Development

NOVEMBER 29, 1982

SEMI-ANNUAL PROGRAM REVIEW PRESENTATION TO LEVEL 1, INTERAGENCY COORDINATION COMMITTEE



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15. Supplementary Notes

16. Abstract

This is the sixth semi-annual presentation of the Inventory Technology Development (ITD) project status to AgRISTARS Level 1, Interagency Coordination Committee on November 30, 1982. It represents accomplishments primarily from April 1, 1982 through September 30, 1982.

17. Key Words (Suggested by Author(s))	18. Distribution Statement

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THIS IS THE SIXTH SEMIANNUAL PRESENTATION OF THE INVENTORY TECHNOLOGY DEVELOPMENT (ITD) PROJECT STATUS TO AGRISTARS LEVEL 1, INTERAGENCY COORDINATION COMMITTEE ON NOVEMBER 30, 1982. IT REPRESENTS ACCOMPLISHMENTS PRIMARILY FROM APRIL 1, 1982 THROUGH SEPTEMBER 30, 1982.

James L. Dragg

for JON D. ERICKSON
ITD PROJECT MANAGER

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OVERVIEW OF ITD ACCOMPLISHMENTS AND CHANGES

(OCTOBER 1981-MARCH 1982)

- ITD CONTINUED TO BUILD ON ACCOMPLISHMENTS OF PREVIOUS PERIOD
  - FURTHER QUANTIFIED MAJOR SOURCE OF SSG ERRORS TO BE IN ACQUISITION SELECTION - ASSOCIATED WITH SATELLITE OVERPASS FREQUENCY AND CLOUD COVER.
  - SIGNIFICANT IMPROVEMENT MADE IN ACCURACY AND EFFICIENCY OF POST-TASSELING CORN AND SOYBEANS PROCEDURES.
  - BEGAN TO EXTEND TECHNOLOGY TO INCLUDE WINTER SMALL GRAINS FOR USSR APPLICABILITY.
- PROGRESS CONTINUES TO BE MADE ON KEY TECHNICAL PROBLEMS.
- PROMISING PRELIMINARY RESULTS HAVE BEEN OBTAINED FOR NEW APPROACHES TO AREA ESTIMATION
  - EARLY SEASON
  - CHANGE ESTIMATION
- THE GOALS OF FOREIGN APPLICABLE TECHNOLOGY AND UNDERSTANDING TO SUPPORT SATELLITE AND SENSOR SYSTEMS DEFINITION HAVE BEEN RETAINED.
- TESTING OVER REGIONS AND YEARS OF SIGNIFICANT VARIABILITY, WHICH WAS BELIEVED TO BE IMPORTANT TO UNDERSTANDING THE DIRECTION OF RELIABLE TECHNOLOGY DEVELOPMENT, HAS BEEN RELUCTANTLY DELETED.

OVERVIEW OF ITD ACCOMPLISHMENTS
(APRIL 1 TO SEPTEMBER 30, 1982)

- INITIAL TM DATA RECEIVED AND ANALYZED
  - NO INDICATION OF INSTRUMENT OR SERIOUS GROUND PROCESSING PROBLEMS
    - + THERMAL BAND NOT FULLY EVALUATED
  - STRONG EVIDENCE OF GREATLY INCREASED INFORMATION CONTENT OVER MSS
- SIGNIFICANT FINDINGS WERE MADE IN THE SELECTION OF VARIABLES FOR CROP SEPARABILITY
- EARLY SEASON SPRING SMALL GRAINS ESTIMATOR DEVELOPED/IMPROVED
  - ESTIMATES WITHIN ONE MONTH OF PLANTING
  - INDICATED PERFORMANCE VERY GOOD
  - REGISTRATION NOT REQUIRED
  - IMPLEMENTED ON USDA FCCAD SYSTEM UNDER DIRECTION OF AD-HOC APPLICATIONS RESEARCH TEAM
- DEVELOPMENT OF AGRICULTURAL INFORMATION SYSTEM SIMULATOR COMPLETED
  - SIMULATES ORBITS, CLOUD COVER, PROPORTION ESTIMATES, LARGE AREA ESTIMATES
  - SIGNIFICANT RESULTS HAVE ALREADY BEEN OBTAINED

OVERVIEW OF ITD ACCOMPLISHMENTS
(APRIL 1 TO SEPTEMBER 30, 1982)
(CONTINUED)

- SIGNIFICANT PROGRESS MADE IN OTHER AREAS
  - TECHNIQUES NOT REQUIRING REGISTRATION
  - SAMPLING AND AGGREGATION
  - WINTER GRAINS LOGIC
  - UNDERSTANDING OF PREVIOUS SPRING SMALL GRAINS AND CORN/SOBYEANS/ SUMMER CROPS EXPERIMENTAL RESULTS
  - INVESTIGATIONS ON UTILITY OF AVHRR, CZCS, SIR-A, AND LFC DATA

ITD FY82
SUMMARY ACCOMPLISHMENTS
(APRIL 1, 1982 TO SEPTEMBER 30, 1982)

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT

- o SMALL GRAINS
  - o FURTHER DEVELOPMENTS IN PREVIOUSLY REPORTED EARLY SEASON SPRING SMALL GRAINS ESTIMATOR (SSG5)
    - + RETAINS PREVIOUS ADVANTAGES
      - - ESTIMATE WITHIN MONTH AFTER PLANTING
      - - UNITEMPORAL; NO REGISTRATION REQUIRED
      - - HIGH PROCESSABILITY (>60%)
      - - LITTLE OR NO ANALYST INTERVENTION
    - + TRANSFER TO FCCAD LARGELY COMPLETE
      - - VALIDATED USING FCCAD SELECTED VEGETATION INDEX NUMBER
    - + IMPROVED BY INCLUSION OF STRATUM-LEVEL PRIOR PROBABILITIES
      - - BIAS REMAINS SMALL (RELATIVE MEAN ERROR = 1.04% OVER 100 1976-1979 SAMPLE SEGMENT YEARS)
      - - VARIANCE REDUCED TO LEVELS NEAR MANUAL INTENSIVE PROCEDURES (STANDARD DEVIATION = 7.5%)
    - + APPLICABLE TO U.S., U.S.S.R.; FURTHER RESEARCH NEEDED FOR OTHER REGIONS, CROPS

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- O SMALL GRAINS (CONTINUED)
  - O VARIABLE SELECTION METHODOLOGY DEVELOPED AND SPRING SMALL GRAINS STUDY PERFORMED
    - + ESTIMATED THE CLASSIFICATION ACCURACY ACHIEVABLE AS FUNCTIONS OF
      - - LANDSAT PREPROCESSING TRANSFORMATION USED
      - - VEGETATIVE MEASURE USED
    - + SHOWED BEST COMBINATION OF OPTIONS DEPENDENT ON CROP MIX, TIME IN SEASON
      - - SCENE MEAN NORMALIZATION PREPROCESSING TRANSFORM BEST IN EARLY, LATE SEASON
      - - SUCCESS OF EARLY SEASON ESTIMATOR DUE TO SCENE MEAN NORMALIZATION
    - + SUPPORTED SELECTION OF VEGETATIVE INDEX NUMBER BY FCCAD
    - + IDENTIFIED ADDITIONAL VARIABLES AND PERIODS FOR POTENTIAL BARLEY SEPARATION

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- SMALL GRAINS (CONTINUED)
  - FURTHER DEVELOPMENTS IN PREVIOUSLY REPORTED SPRING SMALL GRAINS PROFILE CHANGE ESTIMATOR (SSG6)
    - + PREVIOUSLY REPORTED ADVANTAGES
      - PRECISE REGISTRATION NOT REQUIRED
      - FOREIGN ADAPTATION BELIEVED EASIER THAN EARLY SEASON ESTIMATOR
      - LITTLE OR NO ANALYST INTERVENTION
    - + SPARSITY OF MULTIYEAR GROUND TRUTH SITES CONTINUES TO WEAKEN CONCLUSIONS
      - SIMULATION BASED ON RECENTLY DEVELOPED DATA BASES EXPECTED TO SOLVE PROBLEM
    - + STRATUM LEVEL ESTIMATOR DEVELOPED
      - OBTAINS REASONABLE RESULTS WHEN ACQUISITION HISTORY APPARENTLY INADEQUATE FOR SEGMENT LEVEL ESTIMATES
    - + TEST OVER SEVEN VEGETATIVE INDICES CONDUCTED
      - IN SUPPORT OF FCCAD/ITD AD HOC APPLICATIONS RESEARCH TEAM
      - RESULTS SUGGEST TECHNIQUE USABLE WITH AVHRR
    - + EXPECT TO EXPAND TO AVHRR
      - BETTER ACQUISITION HISTORY
      - MORE TIMELY DATA

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- SMALL GRAINS (CONTINUED)
  - + PROBLEMS IDENTIFIED IN MIXED WINTER/SPRING SMALL GRAINS ENVIRONMENTS
    - - CAN REFORMULATE PROFILE CHANGE ESTIMATOR USING EARLY SEASON ESTIMATOR CONCEPTS - MAY SOLVE MIXED CROP PROBLEMS

- LARGE UNIT PROPORTION ESTIMATION
  - + AMENABLE TO CURRENT FCCAD ENVIRONMENT
    - - PRECISE REGISTRATION NOT REQUIRED
    - - USES SKIP SAMPLED FULL-FRAME DATA
  - + BASED ON SSG4 TYPE TECHNOLOGY CLASSIFYING AGRICULTURAL REGIONS (RATHER THAN FIELDS) FOR WINTER/SPRING SMALL GRAINS AND SUMMER CROPS
  - + AUTOMATED APPROACH FOR MAPPING
  - + FEASIBILITY TEST PROCESSED USEABLE 2/3 OF EACH OF 3 LANDSAT 3 1980 FULL FRAMES IN KS, NB
    - - RESULTS COMPARED TO USDA COUNTY STATISTICS
      - -- WINTER GRAINS MEAN ERROR = -0.9% 4.2% RME
      - -- SUMMER CROPS MEAN ERROR = 2.3% 15% RME

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- SMALL GRAINS (CONTINUED)
  - DEVELOPMENT OF TRADITIONAL MULTITEMPORAL MSS PROCEDURES ON NEARLY TERMINATED DUE TO
    - + PROGRESS IN NON-REGISTERED DATA APPROACHES
    - + TRADITIONAL APPROACHES NOT SOON APPLICABLE TO FCCAD
    - + LIMITED RESOURCES
    - + TRADITIONAL APPROACHES NOW CONCENTRATED ON TM, WHERE NEWER APPROACHES NOT YET APPROPRIATE
  - DEVELOPMENT OF INTEGRATED WINTER AND SPRING SMALL GRAINS PROCEDURE (SG-1)
    - + DEVELOPMENT OF WINTER GRAINS LOGIC MODULE COMPLETE
      - - INTEGRATION WITH SPRING GRAINS NOT COMPLETE
    - + AUTOMATED PIXEL RELOCATION TESTED AND SHELVED
      - - AUTOMATION OF PREVIOUSLY MANUAL STEP (STEP BYPASSED IN 1981-82 PILOT)
      - - INTENDED TO OBTAIN LABELING ADVANTAGES OF PURE PIXELS WITHOUT INCURRING BIAS
      - - INTENT ACHIEVED, BUT EFFECT ON PROPORTION ESTIMATES NEGLIGIBLE

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- SMALL GRAINS (CONTINUED)
  - COMPLETION OF 1981-82 PILOT EXPERIMENT LABELING STUDIES
    - + ERRORS SIMILAR IN DEGREE AND TYPE TO PREVIOUS MANUAL INTENSIVE PROCEDURES
      - ACQUISITION HISTORY
      - BOUNDARY PIXEL

- CORN/SOYBEANS/SUMMER CROPS
  - CURRENT RESULTS WITH REGISTERED DATA HIGHLY ENCOURAGING
    - + SR BADHWAR AUTOMATED TECHNOLOGY
    - + LATEST ITD AUTOMATED RESULTS

	CORN	SOYBEANS	SUMMER CROPS
MEAN ERROR	1.5%	-0.2%	0.8%
STANDARL DEVIATION	4.7	3.5	4.5
NUMBER OF SEGMENTS	18	18	22

    - + BOTH APPEAR TO PROVIDE ADEQUATE SOLUTIONS IF REGISTERED DATA AVAILABLE (EXTENSION TO FOREIGN REGIONS STILL AN ISSUE)
    - + WOULD RECOMMEND PILOT EXPERIMENT IF FUNDS AVAILABLE

CROP ID/LABELING/PROPORTION ESTIMATION TECHNOLOGY DEVELOPMENT (CONTINUED)

- o CORN/SOYBEANS/SUMMER CROPS (CONTINUED)
  - o HOWEVER, SINCE REGISTERED DATA NOT AVAILABLE TO FCCAD, ITD INTENDS TO LIMIT RESOURCES APPLIED TO "TRADITIONAL" APPROACHES TO CORN/SOYBEANS/SUMMER CROPS
    - + IN FAVOR OF TECHNIQUES NOT REQUIRING PRECISE REGISTRATION
      - - EARLY-SEASON/PROFILE CHANGE - LIKE APPROACHES AND LARGE UNIT PROPORTION ESTIMATION
  - o GROUND TRUTH FIELDS/MSS DATA BASE CONSTRUCTED FOR PROCEDURE DEVELOPMENT
    - + WILL SUPPORT APPLICATION OF SMALL GRAINS EARLY SEASON ESTIMATOR APPROACH TO CORN/SOYBEANS/SUMMER CROPS
    - + ALSO SUPPORTS SMALL GRAINS, LARGE UNIT PROPORTION ESTIMATION
      - -- 57 SEGMENT YEARS (1978 AND 1979)
      - -- DETAILED STATISTICS ON EACH FIELD

FEATURE IDENTIFICATION

- AUSTRALIAN SIGNATURE CHARACTERIZATION
  - ANALYSIS OF 79-80 SEASON DATA NEAR COMPLETION
    - + SUGGESTS APPLICABILITY OF AUTOMATED PROCEDURES
  - DATA CATALOG OF 20 81-82 SEASON GROUND TRUTH SITES COMPLETE
    - + MSS DATA QUALITY PROBLEMS STILL BEING WORKED WITH GSFC
      - - DATA NOT UNUSEABLE IN ANY CASE
  - METEOROLOGICAL DATA PREPARED FOR SITES OF INTEREST
- ARGENTINA SIGNATURE CHARACTERIZATION
  - INTENSIVE EXAMINATION OF SEGMENT WITH BEST GROUND/MSS DATA SET
    - + RESULTS INDICATE US-BASED TECHNIQUES APPLICABLE
- USSR SIGNATURE CHARACTERIZATION
  - EFFORT TERMINATED DUE TO LACK OF RESOURCES, LOSS OF CIVIL SERVANT COUNTRY ANALYST

FEATURE IDENTIFICATION (CONTINUED)

- PHYSICALLY BASED COMPARISON STUDY OF SEVERAL MSS VEGETATIVE INDICES PERFORMED
  - GREENNESS MOST LINEAR
  - 7/5 RATIO EXCELLENT FOR DISCRIMINATING THIN VEGETATION FROM SOIL, BUT HIGHLY NON-LINEAR FOR DENSE VEGETATION
  - NORMALIZED DIFFERENCE, TRANSFORMED VEGETATION INDEX ACHIEVE ADVANTAGES OF 7/5 RATIO WITH REASONABLE LINEARITY

SAMPLING AND AGGREGATION/PERFORMANCE ESTIMATION AND PREDICTION

- O AGRICULTURAL INFORMATION SYSTEM SIMULATOR
  - O DEVELOPMENT, TESTING, AND CONFIGURATION COMPLETE
  - O FIRST ANALYSIS RESULTS OBTAINED, COMPARING LANDSAT-D ORBIT TO LANDSAT 1, 2, 3, ORBIT
    - + LANDSAT D ACHIEVED SLIGHTLY BETTER ACQUISITION RATE DESPITE SEGMENT ALLOCATION (RANDOMLY) FAVORING LANDSAT 1, 2, 3
    - + INTERACTION OF WEATHER PATTERNS AND SATELLITE LAUNCH DATA A MAJOR SOURCE OF PROCESSABILITY VARIANCE
    - + LANDSAT D ACQUISITION RATES APPEAR LESS SENSITIVE TO WEATHER THAN DO LANDSAT 1, 2, 3
- O COMPLETED EVALUATION OF ADVANCED AGGREGATION TECHNOLOGIES (FOUR AGGREGATION PROCEDURES)
  - + SINGLE YEAR VS. MULTIYEAR: SIMPLE RATIO FOR MISSING STRATA VS. MATHEMATICALLY OPTIMAL ADJUSTMENT
  - O EVALUATION SHOWED BOTH ADVANCED PROCEDURES REDUCED VARIANCES
    - + 40% AVERAGE VARIANCE REDUCTION ACHIEVED BY SIMULTANEOUS APPLICATION
    - + MULTIYEAR MODEL INTRODUCED SMALL BIAS (~3%)

SAMPLING AND AGGREGATION/PERFORMANCE ESTIMATION AND PREDICTION (CONTINUED)

- SAMPLING/AGGREGATION FOR CHANGE
  - FCCAD UTILIZED ITD DEVELOPED SYSTEM IN USSR 1982 CROP YEAR OPERATIONAL TEST
  - INITIAL DEVELOPMENT OF LINE INTERSECT SAMPLING APPROACH
    - + OPTIMAL FOR DETECTION,LOCATION OF CHANGE
    - + FUNDED BY UNIVERSITY OF HOUSTON, FOLLOW-ON TO BE FUNDED BY ITD
- PLAN UNDER DEVELOPMENT TO DEVELOP/IMPLEMENT AGGREGATION SYSTEM IN RESPONSE TO FCCAD REQUEST/REQUIREMENTS
  - ORIENTED TO GRID CELLS, NOT SEGMENTS
  - NOT CURRENTLY FUNDED

FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION

- EXTRACTION OF COMMON FEATURES OF MSS, AVHRR AND CZCS INVESTIGATED WITH FIELD MEASUREMENTS DATA
  - AVHRR RELATION TO MSS
    - BRIGHTNESS $R^2 > .99$
    - GREENNESS $R^2 > .99$
  - CZCS RELATION TO MSS
    - BRIGHTNESS $R^2 > .99$
    - GREENNESS $R^2 > .99$
  - AVHRR GREENNESS LESS SENSITIVE TO SOIL COLOR THAN MSS

FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION (CONTINUED)

- THEMATIC MAPPER
  - FEATURE SPACES DEFINED BOTH FOR BANDS 2, 3, 4 AND 1-5, 7 (ERIM)
    - + BAND 2, 3, 4 SPACE BARELY DISTINGUISHABLE FROM MSS TASSELLED CAP
      - R^2 (BRIGHTNESS) $\geq$ .99
      - R^2 (GREENNESS) $\geq$ .99
    - + IN SIX BAND DATA CROPS AND SOILS TOGETHER OCCUPY FOUR DIMENSIONAL DATA SPACE INCLUDING GREENNESS AND BRIGHTNESS LIKE FEATURES
      - CROPS AND SOILS EACH OCCUPY THREE OF FOUR FEATURES
      - HYPER-PLANES OF CROPS AND SOILS NOT ORTHOGONAL
        - -- IMPLICATION IS THAT BEST TRANSFORM FOR CROPS STUDIES IS NOT BEST FOR SOILS
    - + 6-BAND TM GREENNESS HIGHLY CORRELATED TO MSS GREENNESS ($R^2 \geq .99$)
      - APPEARS MORE SENSITIVE TO VARIATIONS IN SOIL SPECTRAL REFLECTIVITY
    - + 6-BAND TM BRIGHTNESS MORE COMPLEX THAN MSS ($R^2 = .77$)

FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION (CONTINUED)

- O THEMATIC MAPPER (CONTINUED)
  - O QUICK LOOK ANALYSIS
    - + BASED ON:

DETROIT	4 BAND SCENE
MISSOURI/ARKANSAS	7 BAND SCENE
WEBSTER, IOWA	7 BAND TMS (NS-001)

    - + DATA QUALITY CONSISTENT WITH PRELAUNCH EXPECTATIONS
      - RESOLUTION, SIGNAL-TO-NOISE RATIO EXCELLENT EXCEPT THERMAL BAND
      - CONFIRM BAND-TO-BAND MISREGISTRATION
    - + NUMEROUS INDICATIONS OF GREATLY IMPROVED INFORMATION CONTENT
      - FOUR TO SIX USEABLE PRINCIPLE COMPONENT IMAGES
      - IMPROVED SIGNAL-TO-NOISE RATIO CLEARLY OF BENEFIT
      - MID-IR BANDS SHOW FEATURES NOT OTHERWISE VISIBLE
      - CONSIDERABLE REDUCTION IN FRACTION OF MIXED PIXELS

FUTURE SATELLITE AND SENSOR SYSTEM DEFINITION (CONTINUED)

- ENVIRONMENTAL SATELLITE AVHRR*
  - RESEARCH PLAN DEVELOPED
    - + INCLUDED USE OF AVHRR
      - IN PROFILE CHANGE ESTIMATOR
      - IN LUPE
      - TO ASSIST IN MSS ACQUISITION SELECTION AND DESIGNATION
    - + STATUS
      - SOFTWARE PREPARED TO INTERFACE AVHRR WITH EXISTING MSS SYSTEMS
      - DATA ACQUIRED AND REFORMATTED
    - + EFFORT TO CONCENTRATE ON PROFILE CHANGE

* JOINT NASA/NOAA FUNDED

DATA AND DATA SYSTEMS

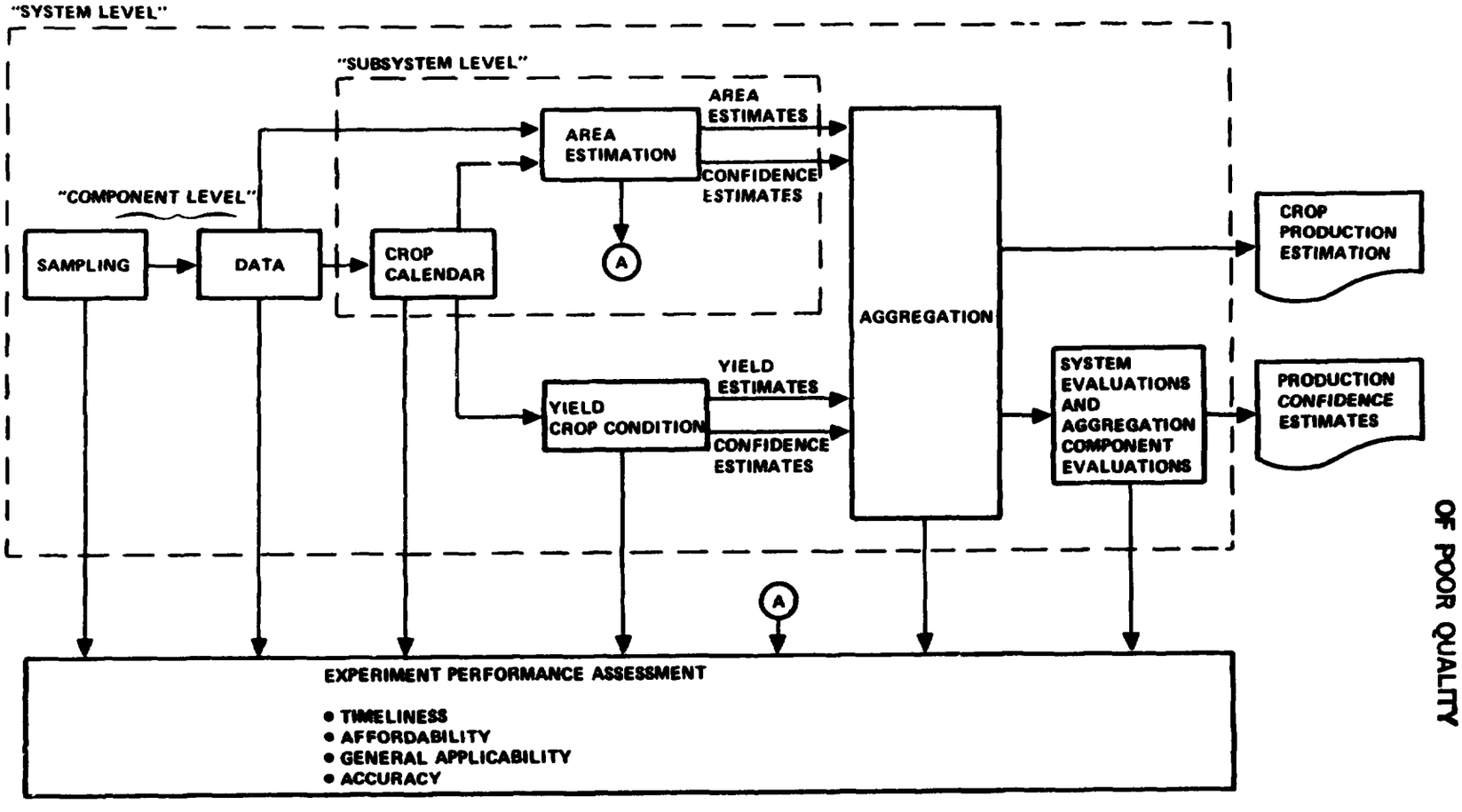
- THEMATIC MAPPER
  - + DATA REQUIREMENTS DEVELOPED (JOINTLY WITH ERRD), SUBMITTED TO GSFC, ARC, USDA
    - - GSFC TM DATA PLAN CREATES SERIOUS ISSUES ON DATA AVAILABILITY
  - + ACQUIRED GROUND TRUTH FOR TECUMSEH, MI SITE (JOINTLY WITH USDA)
  - + DEVELOPED FR-80 SOFTWARE FOR TM IMAGE GENERATION
- AVHRR
  - + 16-BIT UNIVERSAL FORMAT DEVELOPED TO STORE AVHRR 10-BIT DATA, LATITUDE AND LONGITUDE
  - + 58 FOUR-BAND AVHRR SCENES ACQUIRED, SCREENED, REFORMATTED
  - + DISPLAY SOFTWARE DEVELOPED
    - - IMAGE ANALYSIS STATION
    - - FR-80 (PRODUCTION FILM RECORDER)
    - - COLOR GRAPHICS TERMINAL
  - + INTERFACES TO CLASSY, VICAR, ETC. DEVELOPED
    - - CAPABILITY TO EXTRACT GEOPOLITICAL UNITS

DATA AND DATA SYSTEMS (CONTINUED)

- OTHER
  - + AUSTRALIAN 80-81 DATA QUALITY PROBLEMS STILL IN WORK WITH GSFC, ERRD
  - + DEVELOPED GROUND TRUTH FIELDS/MSS DATA BASE FOR PROCEDURE DEVELOPMENT
  - + PREPARED AUSTRALIAN MET DATA AS NEEDED
  - + ACQUIRED, INSTALLED COLOR GRAPHICS TERMINAL, PLOTTER
  - + PREPARED AND DELIVERED COURSES ON CMS AND ADABAS DBMS
  - + TRANSFERRED MET DATA BASE FROM LARS TO JSC
  - + REQUIREMENTS PREPARED FOR FR-80 AND ADABAS DBMS
  - + ACQUIRED OLPARS (ON-LINE PATTERN ANALYSIS AND RECOGNITION SYSTEM) FROM PAR CORP OF ROME, NY
    - - CONSIDERING INITIAL INSTALLATION AT FCCAD (OLPARS NOT READILY ADAPTABLE TO AS-3000)

INVENTORY TECHNOLOGY DEVELOPMENT

AGRICULTURE INFORMATION SYSTEM CONCEPT



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ITD "SYSTEM" CONCEPT

WHAT IT IS NOT!

- A HARDWARE/SOFTWARE SYSTEM FOR DELIVERY.
- THE DESIGN OF A USER OPERATIONAL SYSTEM.

WHAT IT IS!

- A WAY TO ORGANIZE THE "TECHNOLOGY" INTO FUNCTIONAL RELATIONS AND AN INTEGRATED CONTEXT THAT ENABLES RESEARCH AND EVALUATION TO ACCOMPLISH NECESSARY ACTIVITIES.

  -- A MAJOR BENEFIT FROM THE RESEARCH QUALITY DATA BASE AND AND THE EFFICIENCY PROVIDED BY THE AUTOMATED PROCEDURES IS THE RAPID FEEDBACK OF PERFORMANCE RESULTS TO PROCEDURAL DEVELOPMENT.

  -- NOW IT IS POSSIBLE TO VARY THE SUB-COMPONENT WITHIN THE ARCHITECTURE OF THE PROCEDURE AND DETERMINE THE EFFECTS OF THIS CHANGE ON SUB-SYSTEM OR COMPONENT PERFORMANCE ACCURACY, EFFICIENCY, OBJECTIVITY, ETC.

o REPORTING

- TWO PAPERS WERE PRESENTED AT THE AIAA SYMPOSIUM
- TWELVE PAPERS WERE PRESENTED AT THE PURDUE/LARS 8TH INTERNATIONAL SYMPOSIUM
- AN INITIAL SCENE QUICK-LOOK ANALYSIS FOR THE LANDSAT 4 THEMATIC MAPPER WAS PREPARED AND PRESENTED TO GSFC AND NASA HEADQUARTERS.
- ONE PAPER WAS PRESENTED AT THE AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES MEETING SPONSORED BY THE BOTANICAL SOCIETY OF AMERICA
- ONE PAPER PUBLISHED IN THE "REMOTE SENSING FOR RESOURCE MANAGEMENT"
- ONE PAPER WAS PRESENTED AT THE 1982 ACSM-ASP FALL CONVENTION
- TWO PAPERS WERE PRESENTED AT THE MEETING OF AMERICAN STATISTICAL ASSOCIATION
- ONE PAPER WAS PRESENTED TO THE LOUISIANA CHAPTER OF THE ASA
- ONE PAPER WAS PRESENTED AT THE INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING - TOULOUSE, FRANCE
- PREPARED INPUTS TO THE AGRISTARS ANNUAL REPORT, FY82
- SUPPORTED THE AGRISTARS, ITD QUARTERLY TECHNICAL INTERCHANGE MEETINGS

EARLY RESULTS OF THEMATIC MAPPER ANALYSIS

PRELIMINARY THEMATIC MAPPER INVESTIGATIONS

R. BIZZELL

TM INVESTIGATION

BACKGROUND

- O AN UNDERSTANDING OF PERFORMANCE AND FACTORS THAT AFFECT PERFORMANCE OF TM AND MSS SENSORS IS NECESSARY FOR FUTURE PLANNING.

- O SPECIFICALLY, THE TM SENSOR IS DESIGNED FOR:

  - OO INCREASED SPATIAL RESOLUTION
  - OO INCREASED S/N
  - OO INCREASED SPECTRAL RESOLUTION AND ADDITION OF NEW SPECTRAL BANDS

OBJECTIVE

- O QUANTIFY THE TM SYSTEM'S ENGINEERING PERFORMANCE
  - OO EVALUATE DATA QUALITY

- O QUANTIFY THE RESULTING BENEFITS TO AGRICULTURAL/RENEWABLE RESOURCES APPLICATIONS PERFORMANCE
  - OO DETERMINE UTILITY DUE TO IMPROVEMENTS OF THE SENSOR'S CHARACTERISTICS

- O QUANTIFY THE RELATIONSHIP BETWEEN THE TWO

INITIAL STUDY

- O A PRELIMINARY INVESTIGATION BASED ON DATA RECEIVED TO DATE HAS BEEN CONDUCTED - THE DATA INCLUDES THREE SCENES: DETROIT (4 BAND), DES MOINES (4 BAND) MISSISSIPPI RIVER/WESTERN TENNESSEE (7 BAND), TMS DATA OVER WEBSTER COUNTY.

TM DATA STATUS

LOCAL NAME	ROW/PATH	BANDS ACQUIRED	DATE ACQUIRED	NUMBER OF SEGMENTS EXTRACTED (WITH FY82 GROUND DATA)	CONCURRENT MSS	GENERAL CHARACTERISTICS
TOLEDO, OHIO (DETROIT, MICHIGAN)	20/31	1,2,3,4	7/20/82	9 (1)	No	VERY DIVERSE LAND USE CATEGORIES. LARGE & SMALL URBAN AREAS, WATER, EXTRACTION/MINING, NATURAL VEGETATIONS & FOREST, AGRICULTURE - CORN SOYBEANS WHEAT PREDOMINANT CROPS.
MISSISSIPPI RIVER, WESTERN TENNESSEE	23/35	1,2,3,4, 5,6,7	8/22/82	8 (1)	Yes	LARGELY AGRICULTURE INFLUENCED BY THE MISSISSIPPI RIVER PLAIN. PREDOMINANT CROPS--RICE, SOYBEANS, WHEAT, COTTON, CORN, SORGHUM, NATURAL VEGETATION FORESTS, MARSHES, WATER, SMALL TOWNS, AN OBVIOUS TRANSITION FROM FLOOD PLAIN TO UPLANDS ON THE LEFT PORTION OF THE SCENE
DES MOINES, IOWA	27/31	1,2,3,4	8/2/82	1 (3)	No	INTENSIVE AGRICULTURE PREDOMINANTLY--CORN, SOYBEANS.

JSC TM QUICK LOOK SITE SELECTION

GENERAL CRITERIA FOR SEGMENT SELECTION

- O SEGMENTS WERE CHOSEN FOLLOWING CONFIRMATION THAT JSC WOULD RECEIVE A TM SCENE IN THAT AREA.

- O SEGMENTS WITHIN THE SCENE WHERE 1982 GROUND DATA WAS COLLECTED WERE PRIMARY CHOICE:
  - SEGMENT 306 IN THE MISSISSIPPI, AR SCENE
  - SEGMENT 9645 IN THE DETROIT, MI SCENE
  - SEGMENT 893 IN THE DES MOINES, IA SCENE (WEBSTER COUNTY)

- O OTHER SEGMENTS WERE SELECTED TO COVER A VARIETY OF LAND USE GROUPS AND CONDITIONS.

- O SEGMENTS WERE SELECTED TO CONTRIBUTE TO A NUMBER OF THE PLANNED STUDIES.

- O SEGMENTS WERE SELECTED BECAUSE OF THEIR LOCATION ON THE FULL FRAME.

- O THE NUMBER OF SEGMENTS WERE LIMITED DUE TO PROCESSING TIME CONSTRAINTS.

TM PRELIMINARY INVESTIGATION

OBJECTIVES

- ACCOMPLISH A PRELIMINARY UNDERSTANDING OF TM DATA IN A TIMELY FASHION.

SPECIFIC OBJECTIVES

- IS DATA WITHIN RANGE OF ACCEPTABLE/PUBLISHED PERFORMANCE?
- ASSESS UTILITY OF TM DATA WITH CURRENT AVAILABLE AGRISTARS TECHNOLOGY.
- IDENTIFY PROBLEMS THAT AFFECT UTILITY.

STUDIES

TM DATA ASSESSMENT

IMAGE QUALITY STUDY

SPATIAL RESOLUTION QUANTIFICATION STUDY

SIGNAL/NOISE RATIO STUDY

HISTOGRAM ANALYSIS

TM SPATIAL RESOLUTION

PERCENT BOUNDARY/MIXED PIXELS USING AN AUTOMATED FIELD FINDING ALGORITHM

PURE PIXEL STUDY (MANUAL)

SMALL TARGET RECOGNITION

EVALUATION OF TM IMAGERY FOR COLLECTING GROUND TRUTH

TM SPECTRAL ANALYSIS

LAND USE/CROP IDENTIFICATION CAPABILITY AND USEFULNESS OF BANDS/BAND COMPOSITES.

AUTOMATED CLASSIFICATION: VISIBLE/IR COMPARISON

PRINCIPAL COMPONENTS STUDY

MAXIMUM LIKELIHOOD/ISOCLASS

CLUSTERING (CLASSY) STUDY

IMAGE QUALITY AND HISTOGRAM ANALYSIS

OBJECTIVE

- PROVIDE A PRELIMINARY ANALYSIS OF TM DATA QUALITY TO DETECT OBVIOUS DEGRADATIONS

APPROACH

- GENERATE IMAGE PRODUCTS BASED ON COLOR COMPOSITES OF THREE CHANNELS
- GENERATE HISTOGRAMS OF EACH CHANNEL - COMPARE TO MSS HISTOGRAMS
- EVALUATE THESE PRODUCTS VIA OBSERVATIONS REGARDING THE QUALITY OF THE IMAGERY AND FEATURES OF THE HISTOGRAMS

RESULTS OF THE IMAGE QUALITY ANALYSIS

- IMAGE DISTORTION IS FOUND TO BE MINOR
- THE EXTENT OF THE REGISTRATION PROBLEMS IN EXISTENCE AT THE TIME WAS CONSISTENT WITH GSFC EXPECTATIONS
- LOW DYNAMIC RANGE OF THE BLUE CHANNEL DUE TO ATMOSPHERIC EFFECTS WAS AS EXPECTED. THE EFFECT WAS REFLECTED IN THE SIMULATED TRUE COLOR IMAGES.

RESULTS OF THE HISTOGRAM ANALYSIS

- MSS BAND EQUIVALENTS (TM BANDS 2, 3, 4) APPEAR TO HAVE SIMILAR CHARACTERISTICS SUCH AS SHAPE AND RANGE AS THEIR MSS COUNTERPARTS.
- BANDS 5 AND 7 TEND TO HAVE A WIDE RANGE IN THEIR DATA AND BREAK INTO TWO OR MORE CLUSTERS DEPENDING ON THE SCENE COMPOSITION.
- BANDS 1 AND 6 TEND TO HAVE NARROW RANGES AND ARE GENERALLY UNIMODAL. BAND 1 SOMETIMES BECOMES BIMODAL WHEN A DISTINCT WATER/LAND SEPARATION EXISTS.
- WATER APPEARS TO FORM A DISTINCT CLUSTER IN BANDS 1, 4, 5, AND 7.

DATA QUALITY: SIGNAL TO NOISE RATIO

OBJECTIVE

- ASSESS IF TM DATA S/N IS WITHIN SPECIFICATIONS. THE S/N MAY BE A FACTOR IN THE SENSOR'S ABILITY TO DISCRIMINATE BETWEEN SPECTRALLY CLOSE CLASSES.

APPROACH

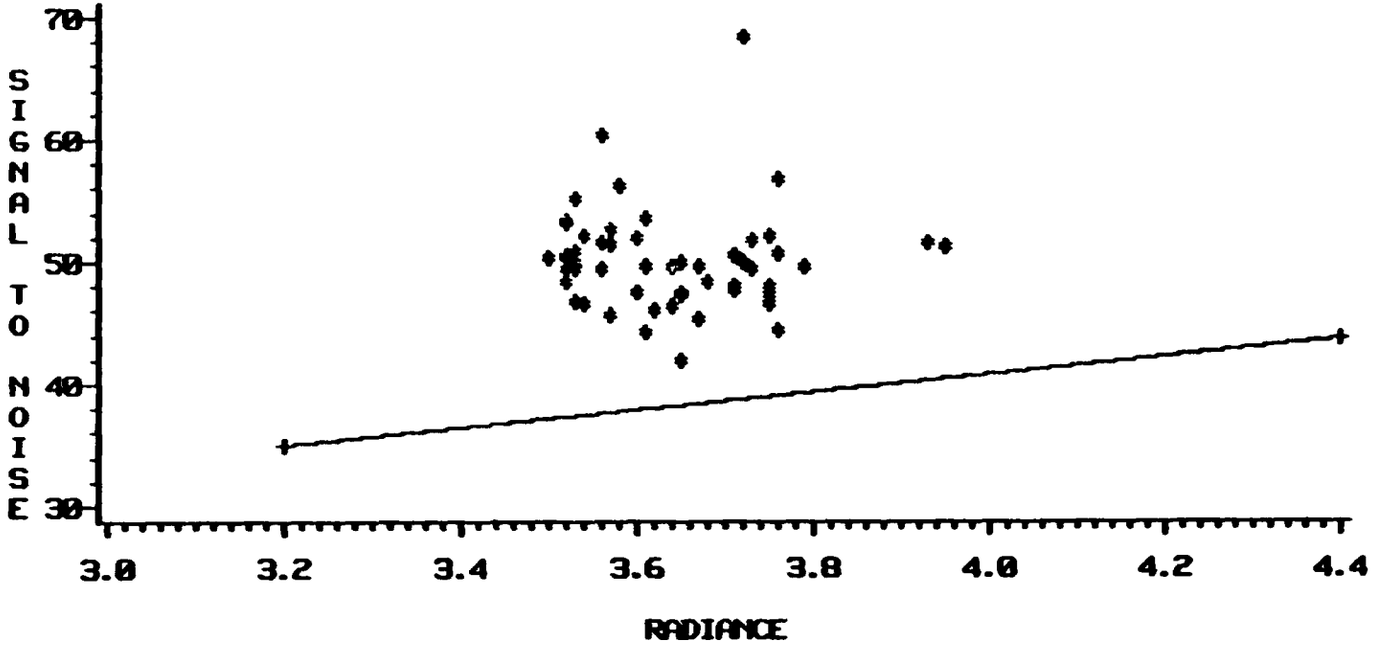
- IDENTIFY HOMOGENEOUS TARGETS ON EACH BAND
- SYSTEMATICALLY RANDOM SAMPLE OVER TARGETS
- CALCULATE S/N BASED ON PIXEL RADIANCE VALUES SAMPLE MEAN AND STANDARD DEVIATIONS (CALCULATE THE NOISE EQUIVALENT TEMPERATURE DIFFERENCE (NETD) FOR BAND 6).
- PLOT OBSERVED S/N AND THE PRE-FLIGHT SPEC.

RESULTS

- S/N RATIOS FOR BANDS 1-5 AND 7 ARE COMPARABLE TO OR ABOVE SPECS.
- RESULTS FOR BAND 6 ARE INCONCLUSIVE. RESULTS INDICATE THAT S/N WAS WORSE THAN SPECS BUT THERE WAS DIFFICULTY IN SELECTING A HOMOGENEOUS TARGET.

TM SIGNAL TO NOISE RATIO

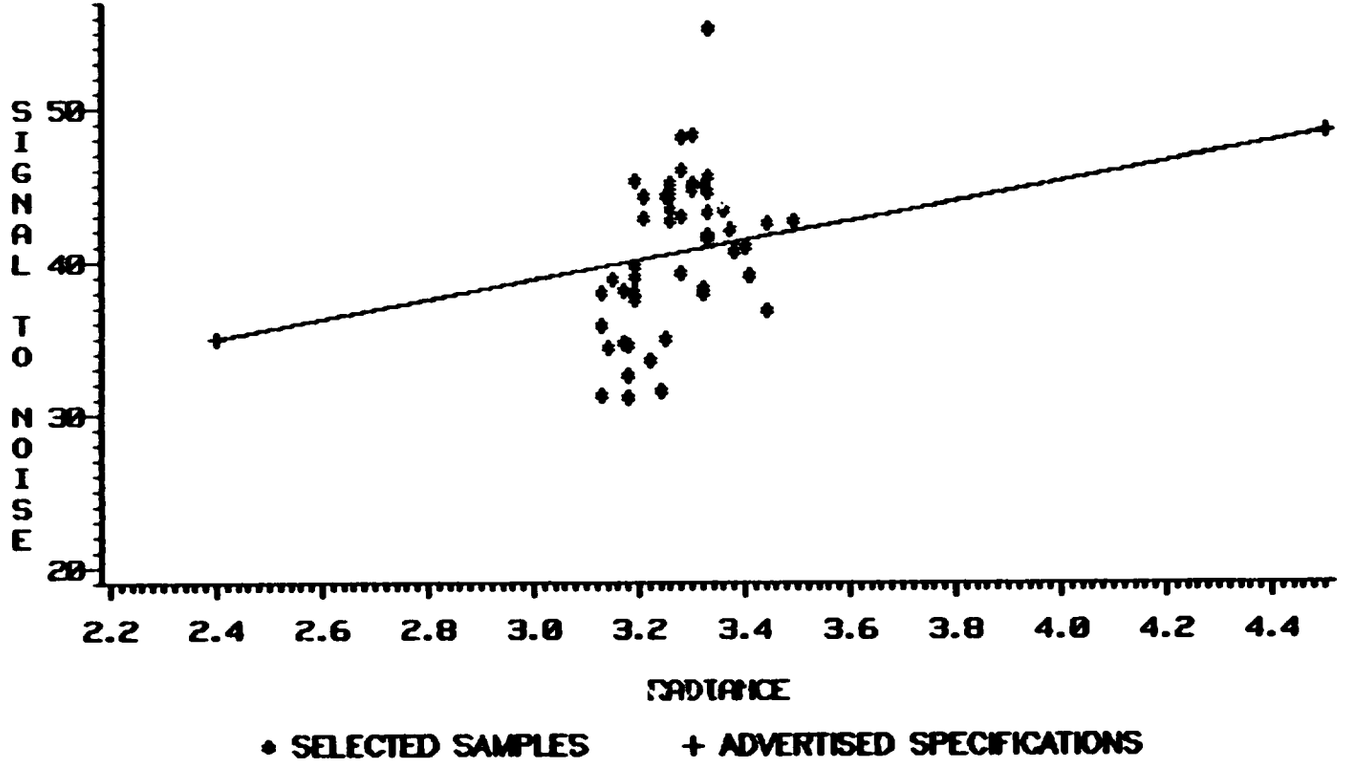
BY RADIANCE FOR BAND1



• SELECTED SAMPLES + ADVERTISED SPECIFICATIONS

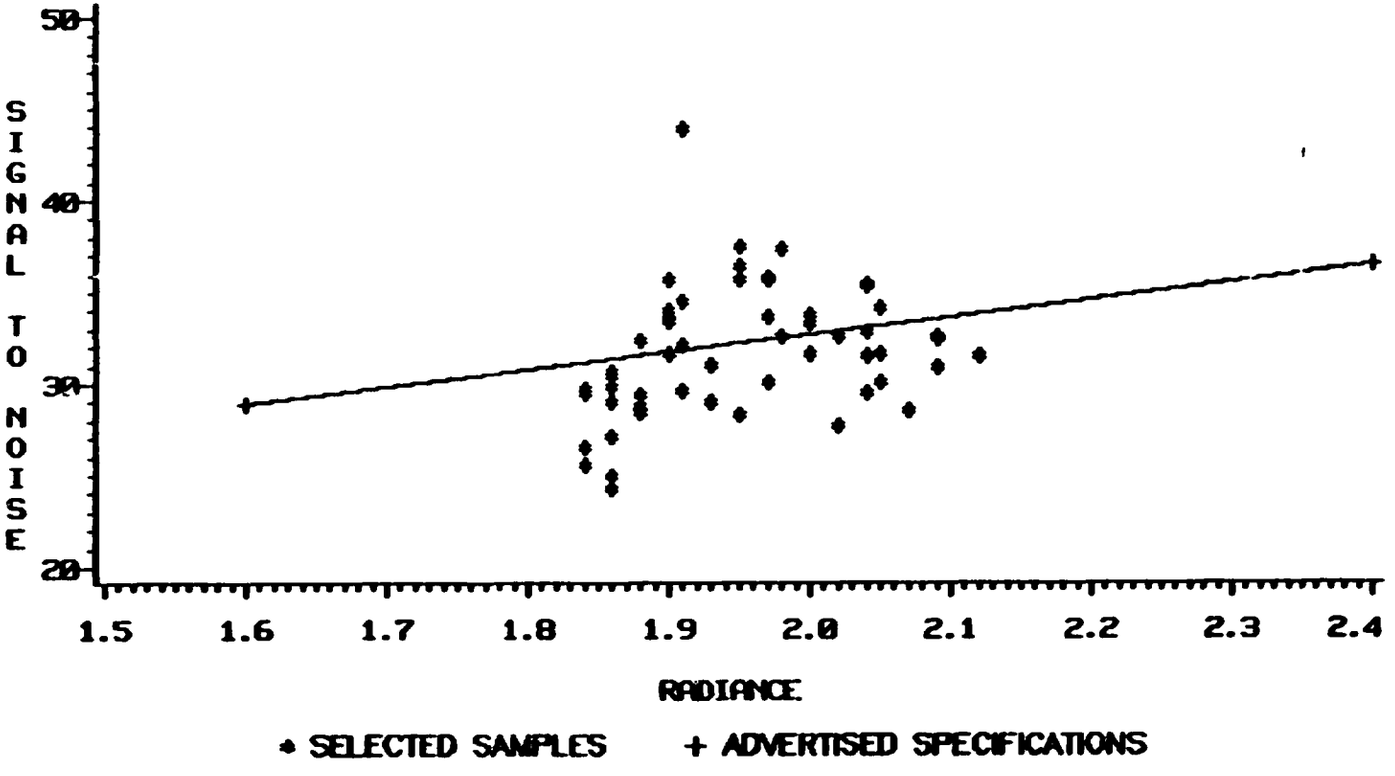
TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND2



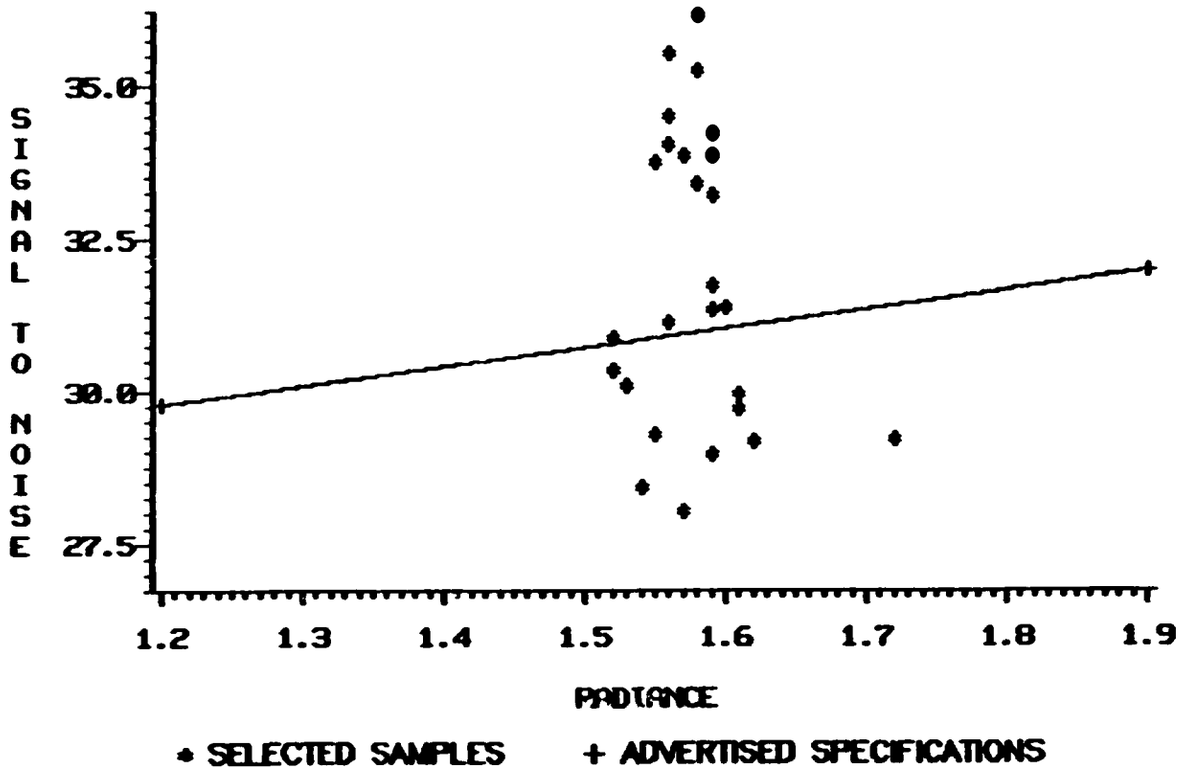
TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND3



TM SIGNAL TO NOISE RATIO

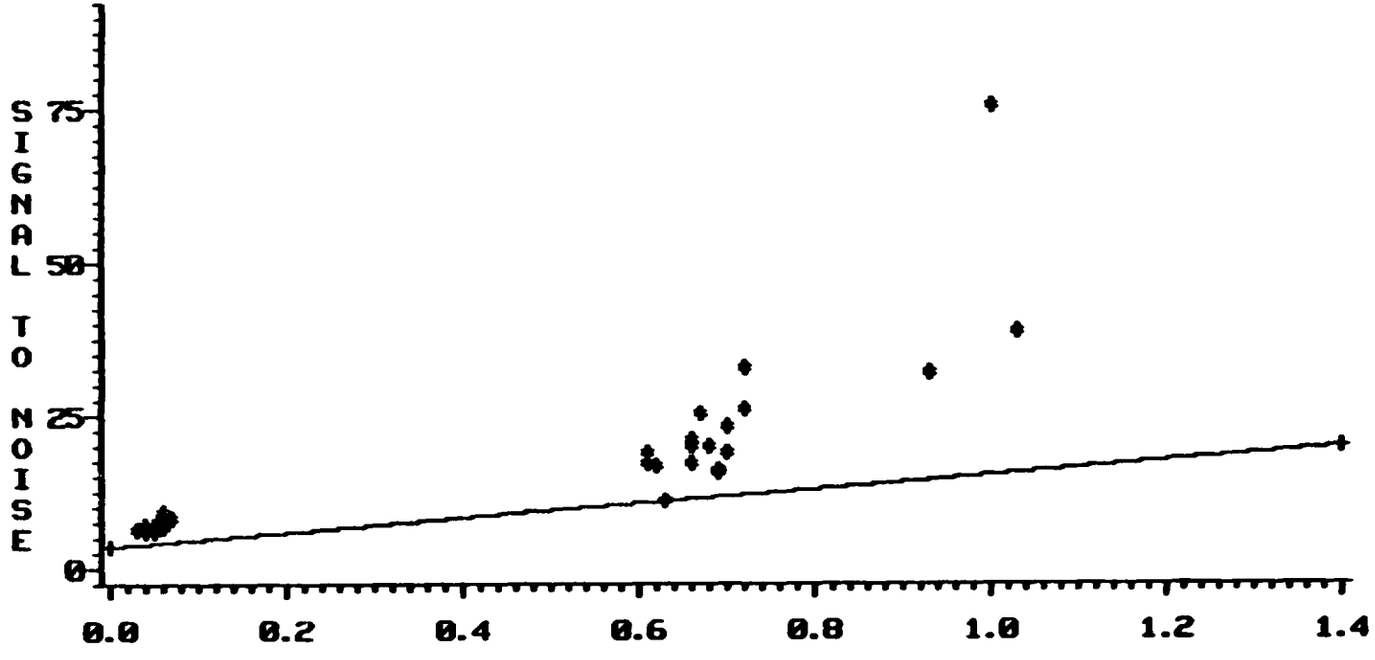
BY RADIANCE FOR BAND4



• SELECTED SAMPLES + ADVERTISED SPECIFICATIONS

TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND5

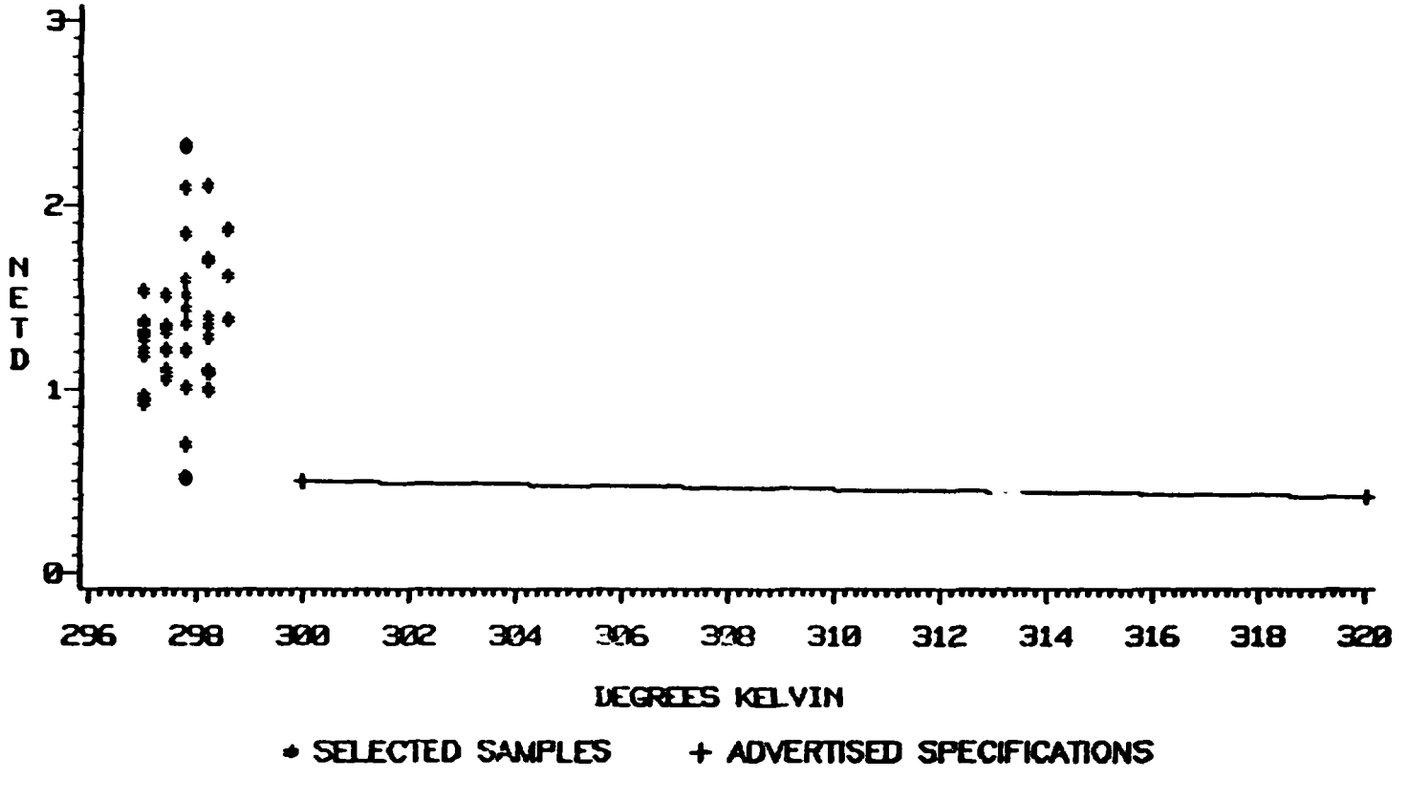


* SELECTED SAMPLES + ADVERTISED SPECIFICATIONS

ORIGINAL PAGE IS
OF POOR QUALITY

TM NOISE EQUIVALENT TEMPERATURE DIFFERENCE

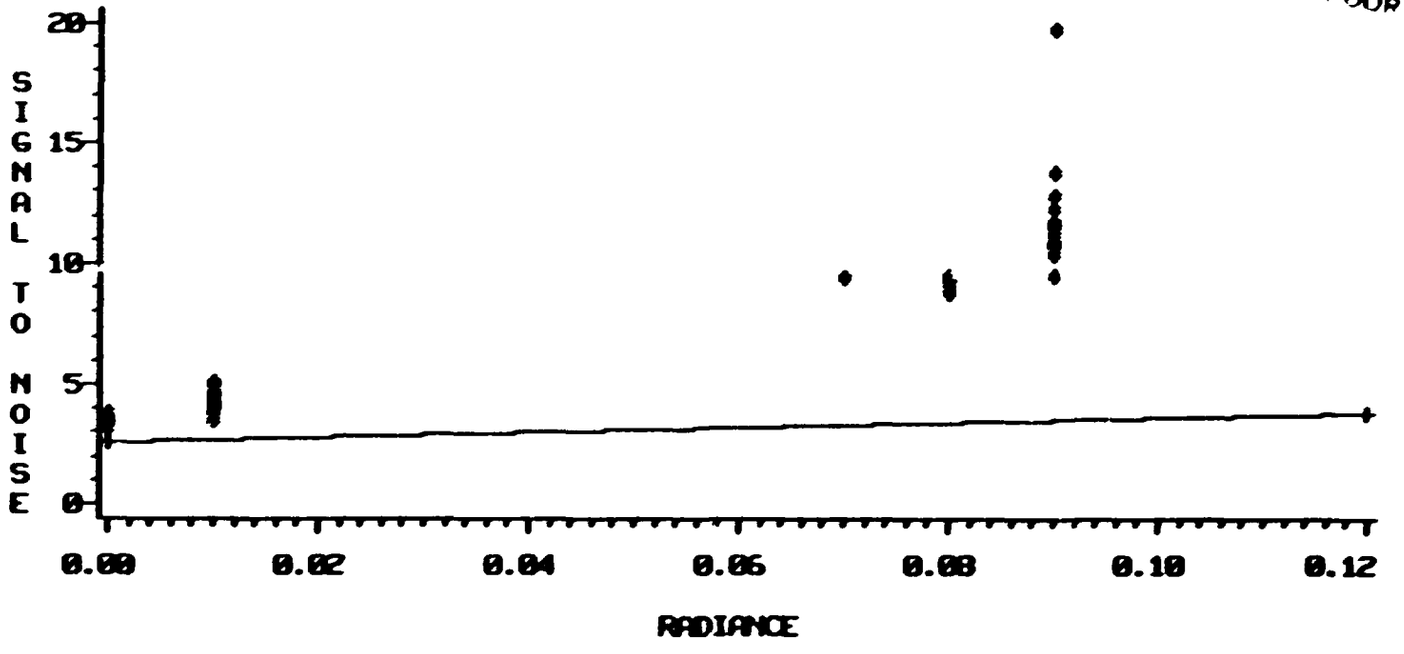
BY DEGREES KELVIN FOR BAND6



HIGHER VALUES FOR NETD INDICATE THAT PERFORMANCE WAS LOWER THAN SPECIFICATIONS.

TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND7



• SELECTED SAMPLES + ADVERTISED SPECIFICATIONS

EQUATIONS TO CALCULATE S/N, RADIANCE AND NETD

- S/N FOR EACH TARGET
- S/N FOR EACH TARGET = $\frac{\text{COUNTS MEAN}}{\text{COUNTS STANDARD DEVIATION}}$

- RADIANCE FOR EACH TARGET = $\alpha + \beta * (\text{COUNTS MEAN})$

  VALUES FOR α AND β WERE OBTAINED FROM GODDARD SPACE FLIGHT CENTER

- NETD = COUNTS STANDARD DEVIATION $* \frac{\text{KELVIN}}{\text{COUNTS}}$

SPATIAL RESOLUTION

OBJECTIVE

- VERIFY AND ASSESS THE BENEFITS OF THE TM SPATIAL RESOLUTION OF APPROXIMATELY 30 METERS.

APPROACHES

- A STUDY TO VERIFY THE DETECTION OF SMALL FEATURES IN TM IMAGERY.
- STUDIES OF RELATIVE CONTENT OF MIXED PIXELS BETWEEN MSS AND TM DATA.
- EVALUATION OF IMAGERY FOR GROUND TRUTH COLLECTION.

RESULTS

- TARGETS OF APPROXIMATELY 30 METERS EASILY DETECTED. AMOUNT OF DETAIL PRESENT IN BANDS 1 THROUGH 5 AND 7 IS SIMILAR.
- RELATIVE MIXED PIXEL CONTENT BETWEEN MSS AND TM DATA -- TWO STUDIES, MANUAL AND AUTOMATIC - INDICATE THAT THE PROPORTION OF MIXED PIXELS IN THE MSS SCENE IS APPROXIMATELY 3 TIMES GREATER THAN IN THE TM SCENE.
- GROUND TRUTH INVENTORY WAS MADE WITH 1:24,000 TM IMAGE AS COLLECTION BASE. FIELD SIZES 1-160 ACRES.

TM SPECTRAL ANALYSIS

OBJECTIVE

- o INVESTIGATE STRUCTURE OF TM DATA
  - IDENTIFY DIMENSIONALITY AND STRUCTURE OF TM FEATURE SPACE.
  - IDENTIFY CORRESPONDENCE TO MSS STRUCTURE.
    (DETAILED PRESENTATION TO FOLLOW)
- o EVALUATE TM DATA FOR CAPABILITY TO DISCRIMINATE BETWEEN GROUND COVER CLASSES (I.E., CROPS, NON-VEG., TREES, ETC)
  - INVESTIGATE TM DATA UTILITY

APPROACH (TO ADDRESS 2ND OBJECTIVE)

- o USE CLUSTERING TECHNIQUES TO INVESTIGATE "NATURAL" CORRESPONDENCE BETWEEN DATA AND GROUND COVER CLASSES.
- o CONDUCT A QUALITATIVE ANALYSIS OF INDIVIDUAL BANDS FOR DISCRIMINATION BETWEEN GROUND COVER CLASSES.
- o APPLY A CURRENTLY AVAILABLE SPECTRAL CATEGORIZATION TECHNIQUE (BASED ON SPATIAL COLOR TECHNIQUE).

TM SPECTRAL ANALYSIS: CLUSTERING

BACKGROUND

- O TWO TECHNIQUES WERE ADAPTED FOR USE WITH TM DATA.
  - ISOCLS - ITERATIVE SELF-ORGANIZING CLUSTERING SYSTEM
  - CLASSY - ADAPTIVE MAXIMUM LIKELIHOOD, UNSUPERVISED

ASSESSMENT OF RESULTS

- O CLUSTERS PRODUCED USING BOTH TECHNIQUES, WHEN COMPARED TO COLOR IR COMPOSITES, CORRESPOND WELL WITH AGRICULTURAL AREAS, NATURAL VEGETATION AND OTHER NON-AGRICULTURAL FEATURES.
  - CLUSTERS GENERATED WITH CLASSY USING TM DATA APPEARED TO CORRESPOND BETTER THAN MSS WITH GROUND COVER CLASSES - INCREASED DETAIL OF SPATIAL FEATURES.
- O UTILIZING A FEATURE SELECTION OPTION TO DETERMINE THE BEST N BANDS FOR MAXIMUM SEPARATION BETWEEN CLASSES, THE FOLLOWING COMBINATION OF BANDS PROVIDED THE BEST SEPARATION FOR THE FOLLOWING CATEGORIES: SUMMER CROPS, NATURAL VEGETATION AND OTHER.

BAND	RATIO*
4	.46
4,5	.74
4,5,3	.88
4,5,3,7	.93

$$*\text{RATIO} = \frac{\text{SEPARABILITY USING SELECTED BANDS}}{\text{SEPARABILITY USING ALL BANDS}}$$

THE SEPARABILITY WAS MEASURED USING THE WEIGHTED AVERAGE DIVERGENCE BETWEEN CLASSES.

TM SPECTRAL ANALYSIS: UTILITY

QUALITATIVE ANALYSIS

BAND 1 - ENHANCED DISCRIMINATION OF CORN/SOYBEANS*, GOOD LAND/WATER CONTRAST. DISTINCT PATTERNS IN WATER - POSSIBLE TURBIDITY/DEPTH EFFECT.

BAND 5 - PATTERNS FORMED BY CHANGES IN INTENSITY OF THE REFLECTED RADIATION ATTRIBUTED TO MOISTURE CONTENT. SMALL PONDS MORE APPARENT THAN IN OTHER MOISTURE DISCRIMINATION BANDS.

BAND 7 - PATTERNS FORMED BY CHANGES OF THE REFLECTED RADIATION ARE HIGHLIGHTED IN AREAS OF LOW VEGETATION. POSSIBLY DUE TO SOIL TYPE/MOISTURE.

BAND 6 - NON-VEGETATIVE REGIONS HIGHLY EMISSIVE - ATTRIBUTED TO WARMER BARE SOIL FIELDS, ETC.

SPECTRAL CATEGORIZATION

- IN GENERAL, THE ADDITION OF THE NEW SPECTRAL BANDS RESULTS IN INCREASED DISCRIMINATION BETWEEN CROPS OR BETWEEN FEATURES RELATED TO CROP CONDITION, I.E.,
  - LATE MATURING CORN AND SOYBEANS*
  - CROP VIGOR RELATED TO WATER CONTENT*

*TMS RESULTS

GENERAL CONCLUSION

- THE TM SENSOR AND ASSOCIATED GROUND PROCESSING IS PERFORMING TO EXPECTATIONS AND WITHIN ADVERTISED SPECIFICATIONS. - A POSSIBLE EXCEPTION IS THE S/N RATIO IN BAND 6. THE KNOWN MISREGISTRATION PROBLEM IN EXISTENCE AT THE TIME WAS NOTED.

- THE TMS DATA PROVIDED BY GISS DID A GOOD JOB OF SIMULATING THE TM AND, THUSLY, PROVIDED MEANINGFUL PRE-TM STUDIES.

- HIGHER SPATIAL RESOLUTION HAS RESULTED IN POTENTIAL BENEFITS FOR AGRICULTURAL APPLICATIONS.
  - AGRICULTURAL AREAS WITH SMALL FIELDS CAN BE PROCESSED.
  - POTENTIAL BIAS INTRODUCED BY THE MIXED PIXEL PROBLEM HAS BEEN DECREASED.
  - IMAGERY WAS FOUND TO BE A SUFFICIENT BASE FOR GROUND COVER/LAND USE GROUND TRUTH COLLECTION IN MOST CASES.

- ADDITIONAL SPECTRAL BANDS HAVE RESULTED IN POTENTIAL BENEFITS FOR AGRICULTURAL APPLICATIONS.
  - IMPROVEMENTS IN SEPARABILITY BETWEEN CROPS AND CROPS AND NON-CROPS, WHICH CAN POTENTIALLY RESULT IN SINGLE ACQUISITION CLASSIFICATION FOR PROBLEMS PREVIOUSLY ADDRESSABLE ONLY MULTITEMPORALLY.

- A CAPABILITY FOR RAPID MANIPULATION OF SMALL VOLUMES OF TM DATA HAS BEEN DEVELOPED WHICH INCLUDES,
  - DATA EXTRACTION AND DIGITAL DATA MANIPULATION.
  - IMAGE DISPLAY AND FILM GENERATION

- FIRST MAJOR STEP IN UNDERSTANDING THE STRUCTURE AND DEFINITION OF TM FEATURE SPACE HAS BEEN TAKEN.

THEMATIC MAPPER FEATURE SPACE IDENTIFICATION

D. Ramey

E. Crist

TOPICS TO BE COVERED:

- o EQUIVALENCE OF THEMATIC MAPPER BANDS 2, 3, 4, AND MULTISPECTRAL SCANNER BANDS 1, 2, 3, 4
  - ++ STUDIES USING SIMULATED DATA
  - ++ STUDIES BASED ON DATA COLLECTED BY LANDSAT 4
- o POTENTIAL OF THEMATIC MAPPER TO PROVIDE ADDITIONAL INFORMATION FOR DISCRIMINATION AND CLASSIFICATION
  - ++ RELATIONSHIP OF THEMATIC MAPPER BANDS 1, 5, 6, 7 AND 2, 3, 4
  - ++ DIMENSIONALITY OF THEMATIC MAPPER DATA
  - ++ FEATURE IDENTIFICATION USING THEMATIC MAPPER DATA

THE EQUIVALENCE OF THEMATIC MAPPER BANDS 2, 3, 4 AND MULTISPECTRAL SCANNER BANDS 1, 2, 3, AND 4--SIMULATED DATA:

- o APPROACH
  - ++ FIELD SPECTROMETER DATA COLLECTED BY LARS
  - ++ THEMATIC MAPPER AND MULTISPECTRAL SCANNER BANDS SIMULATED USING SENSOR RESPONSE CHARACTERISTICS
- o RESULTS
  - ++ HIGH CORRELATION BETWEEN CORRESPONDING BANDS (> .99)
- o CONCLUSION
  - ++ THEMATIC MAPPER AND MULTISPECTRAL SCANNER BANDS CARRY THE SAME INFORMATION FOR THE PURPOSE OF AGRICULTURAL CLASSIFICATION.

THE EQUIVALENCE OF THEMATIC MAPPER BANDS 2, 3, 4 AND MULTISPECTRAL SCANNER BANDS 1, 2, 3 AND 4--LANDSAT 4 DATA:

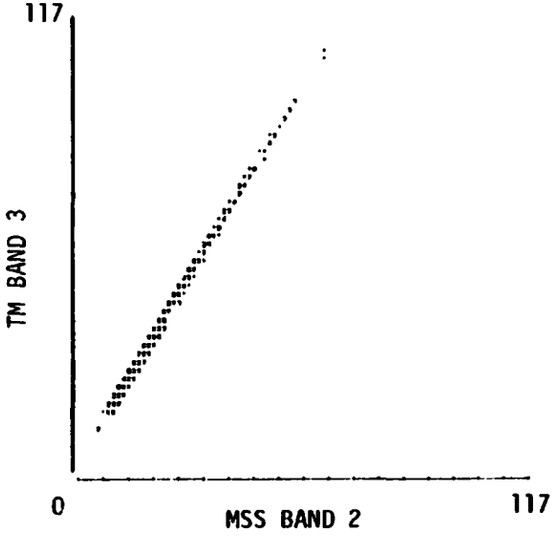
- o APPROACH
  - ++ DATA FROM LANDSAT 4 SAME DAY COVERAGE FOR THEMATIC MAPPER AND MULTISPECTRAL SCANNER DATA
  - ++ SEGMENT 306 (2% WATER, 25% EMERGENT VEGETATION, 73% VEGETATED)
- o RESULTS
  - ++ MODERATE TO HIGH CORRELATIONS (.75 - .94) BETWEEN EQUIVALENT BANDS
- o CONCLUSIONS
  - ++ SIMULATED DATA CONTAINS A SMALLER NUMBER OF CLASSES--WHEAT, CORN, SOYBEANS, AND SOILS
  - ++ SIMULATED DATA CONTAINS A WIDER RANGE OF REFLECTIVITIES
  - ++ POSSIBLE ERRORS IN REGISTRATION OF THE THEMATIC MAPPER AND MULTISPECTRAL SCANNER DATA
  - ++ IN ANY CASE, CORRELATIONS IN BOTH CASES ARE HIGH ENOUGH TO ALLOW APPLICATION OF MULTISPECTRAL SCANNER TYPE TECHNOLOGIES TO THEMATIC MAPPER DATA, GIVEN THE PROPER RESCALING.

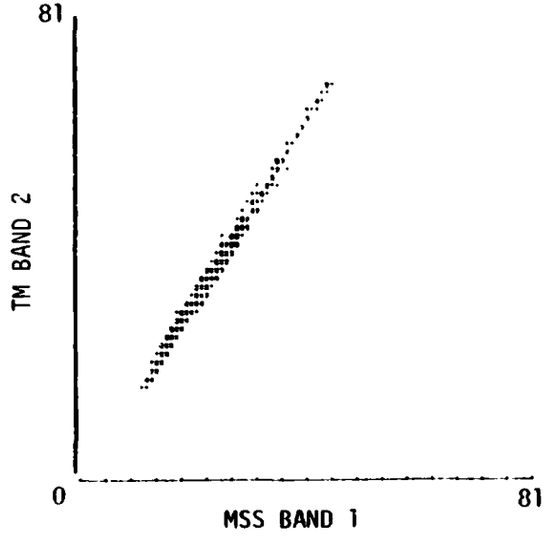
CORRELATIONS OF MSS AND TM BANDS

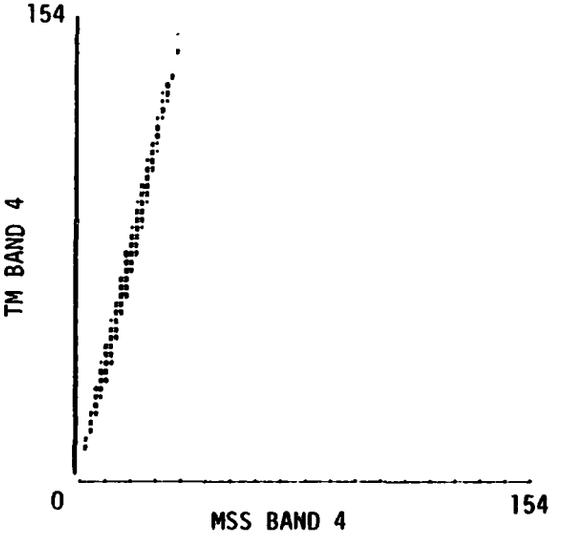
Simulated Counts

CORRELATED COEFFICIENTS

MSS						
1	.93	**.99**	.94	-.01	.79	.78
2	.91	.96	**.99**	-.22	.74	.78
3	-.01	.21	-.03	.97	.15	-.09
4	-.15	.02	-.21	**.99**	.05	-.20
TM	1	2	3	4	5	7





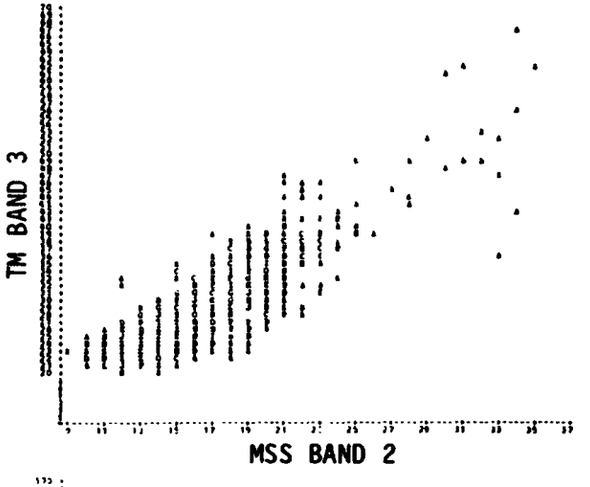


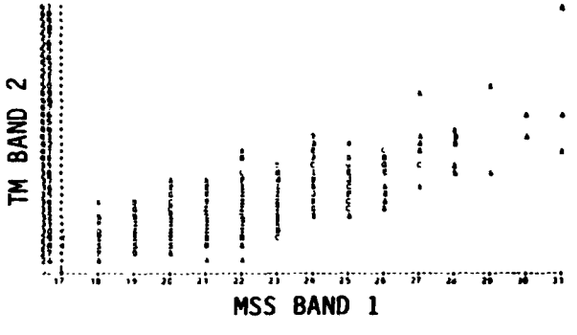
CORRELATIONS OF MSS AND TM BANDS

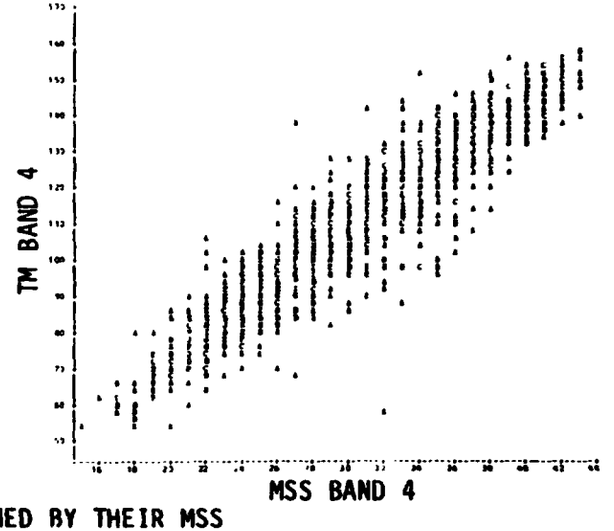
SEGMENT 306

CORRELATION COEFFICIENTS

MSS						
1	.73	[.75]	.74	-.45	.30	.62
2	.84	.82	[.86]	-.57	.36	.75
3	-.41	-.38	.49	[.93]	.31	-.28
4	-.48	-.49	-.57	[.93]	.25	-.35
TM	1	2	3	4	5	7







- o LINEAR RELATIONSHIP
- o SUBSTANTIAL VARIATION IN TM BANDS 2 AND 3 NOT EXPLAINED BY THEIR MSS EQUIVALENTS

POTENTIAL OF THEMATIC MAPPER TO SUPPLY ADDITIONAL INFORMATION FOR DISCRIMINATION AND CLASSIFICATION--REGRESSION STUDY:

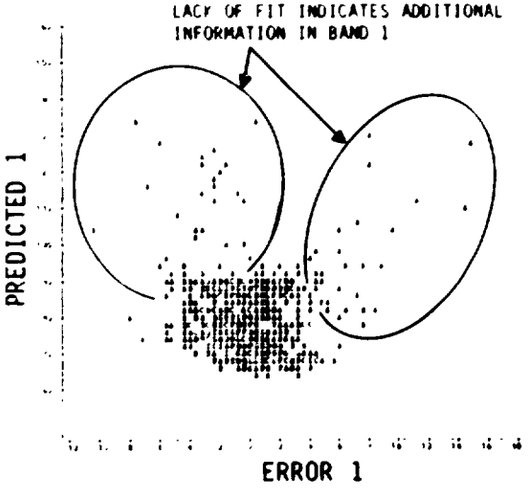
- o ATTEMPTED TO PREDICT THEMATIC MAPPER BANDS 1, 5, 6, AND 7 AS A LINEAR COMBINATION OF THEMATIC MAPPER BANDS 2, 3, AND 4
  - ++ SUCCESS WOULD INDICATE NO ADDITIONAL INFORMATION AVAILABLE.
  - ++ FAILURE WOULD INDICATE POTENTIAL FOR ADDITIONAL USEFUL INFORMATION

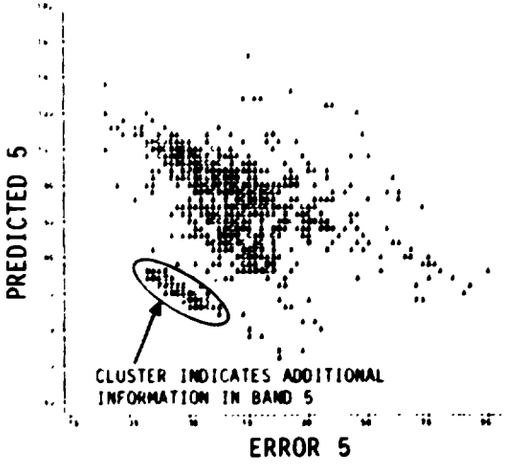
- o RESULTS
  - ++ THE R^2 WAS HIGH, BAND 1
    MODERATE, BAND 5
    LOW, BAND 6
    MODERATE, BAND 7
  - ++ EVIDENCE OF LACK OF FIT FOR ALL PREDICTIVE EQUATIONS FOR AT LEAST ONE OF THE GEOGRAPHICAL AREAS STUDIED
  - ++ COEFFICIENTS NOT STABLE FROM AREA TO AREA

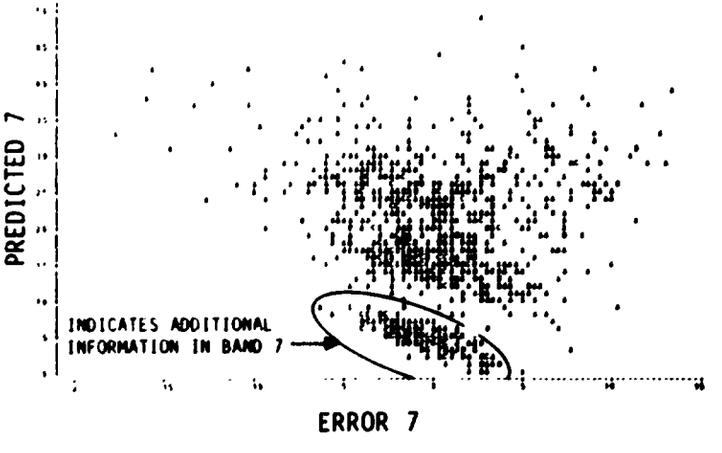
- o EXPLANATIONS AND RECOMMENDATIONS
  - ++ LACK OF FIT AND/OR LOW R^2 INDICATE POTENTIAL FOR ADDITIONAL USEFUL INFORMATION IN THE NEW PORTIONS OF THE SPECTRUM COVERED BY THE THEMATIC MAPPER
  - ++ BAND 1 SHOULD NOT BE IMMEDIATELY WRITTEN OFF, EVEN THOUGH THE R^2 IS HIGH, SINCE THERE IS EVIDENCE OF LACK OF FIT OF THE MODEL.
  - ++ INSTABILITY OF COEFFICIENTS INDICATES RELATIONSHIP NOT CONSTANT OVER VARIOUS TYPES OF LAND COVER.

REGRESSION ANALYSIS: PREDICTION OF NEW TM BANDS FROM MSS EQUIVALENTS

BAND	REGRESSION R^2 LOWEST R^2	HIGHEST R^2
1	.85	.95
5	.55	.88
6	.12	.31
7	.59	.87





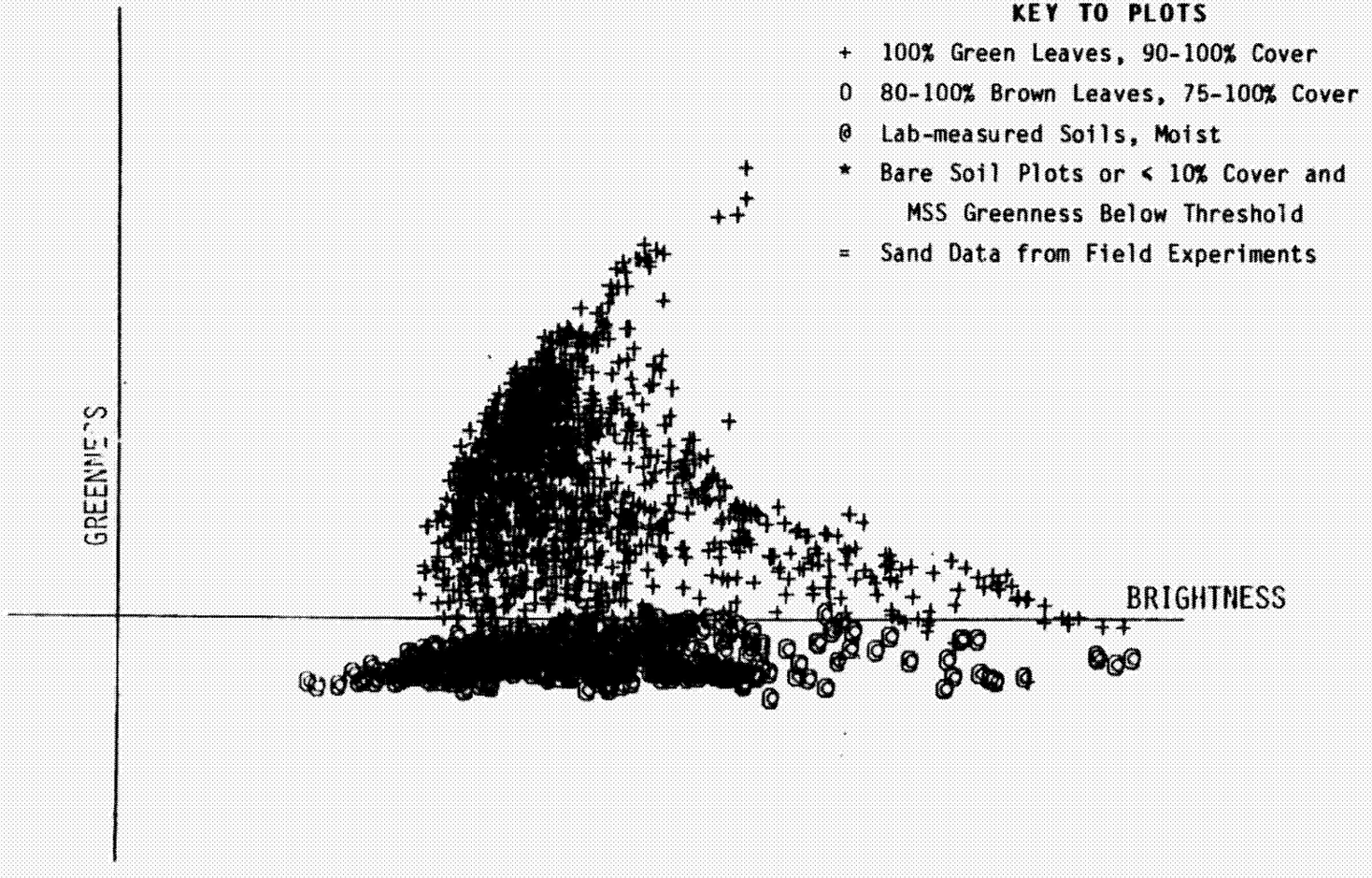


- EVIDENCE OF LACK OF FIT
- CLUSTERS NOT IDENTIFIABLE USING ONLY PREDICTED VALUES

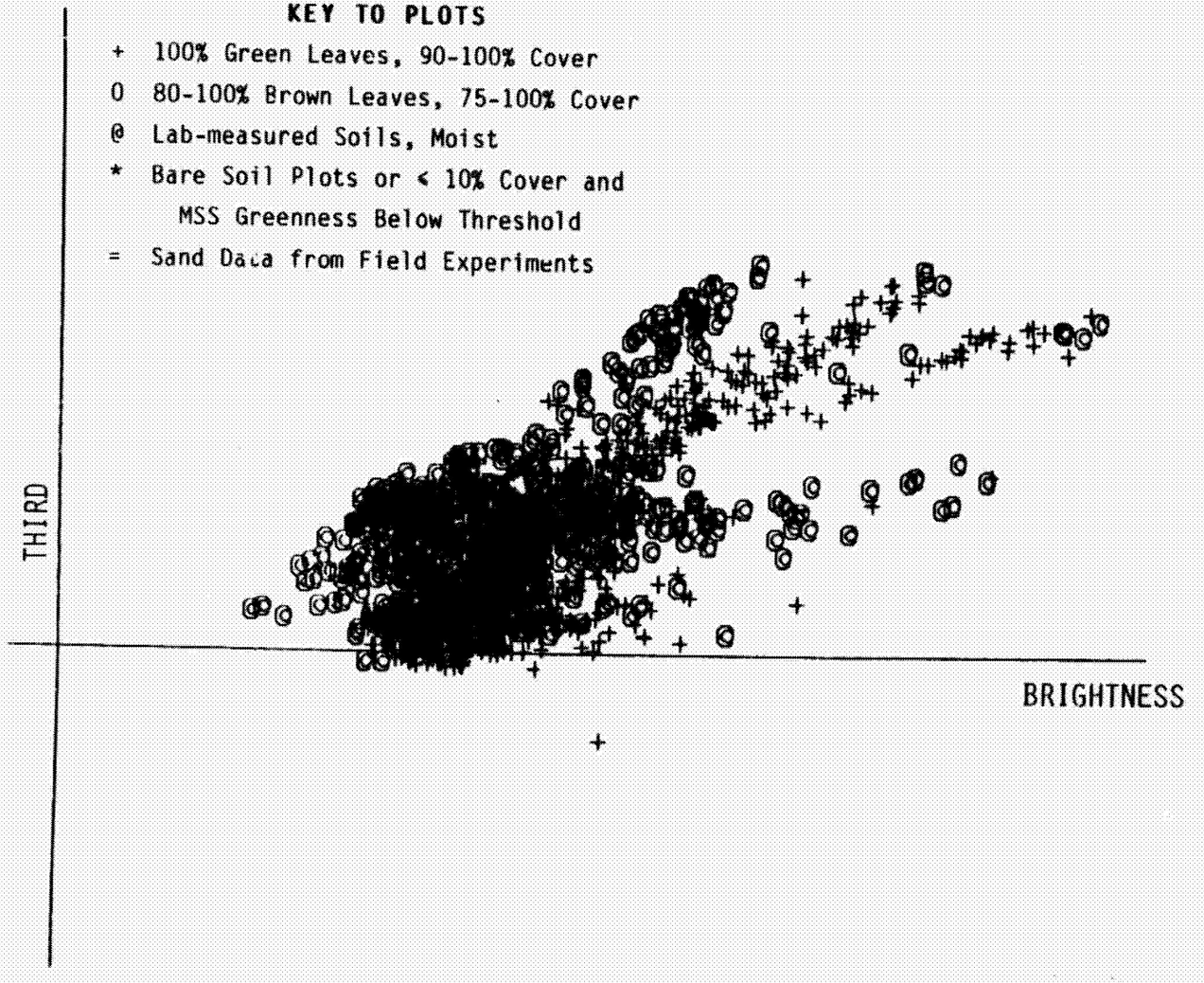
THE DIMENSIONALITY OF THE THEMATIC MAPPER DATA

- O APPROACH
  - ++ STATISTICAL ANALYSES PERFORMED ON BOTH SIMULATED THEMATIC MAPPER DATA AND THEMATIC MAPPER DATA COLLECTED BY LANDSAT 4
  - ++ DATA SPACE ROTATED AND PLOTTED TO MAXIMIZE INFORMATION CONTENT IN EACH PLOTTED DIMENSION
- O RESULTS
  - ++ BOTH STATISTICAL AND GRAPHICAL ANALYSES INDICATE THERE ARE AT LEAST 4 INDEPENDENT DIMENSIONS OF INFORMATION IN THE DATA.
  - ++ VEGETATION AND SOILS EACH PRINCIPALLY OCCUPY A 3 DIMENSIONAL HYPERPLANE
    - THESE HYPERPLANES ARE NOT ORTHOGONAL IN ALL PROJECTIONS
    - IMPLICATION IS BEST TRANSFORMS FOR VEGETATION ARE NOT BEST FOR SOILS
  - ++ APPEAR TO BE BOTH A VEGETATION PLANE OF INFORMATION AND A PERPENDICULAR SOILS PLANE

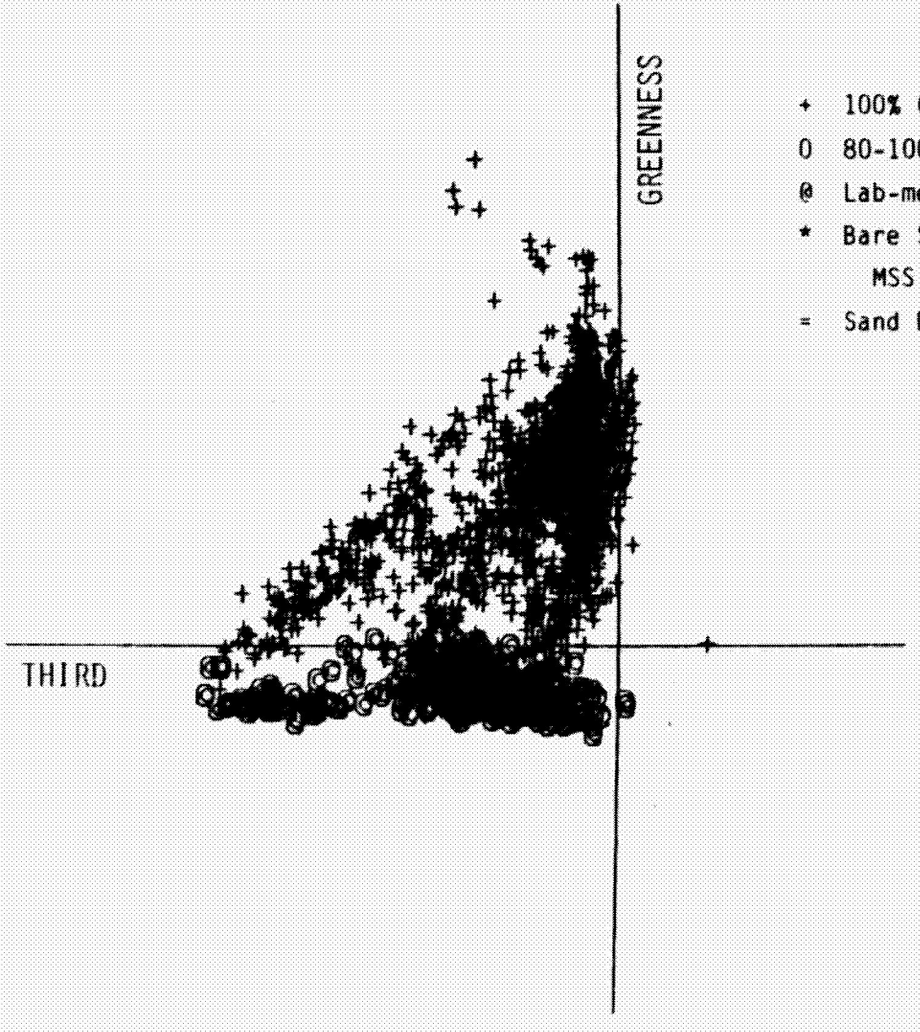
TM PRINCIPAL COMPONENT



TM PRINCIPAL COMPONENTS (Continued)



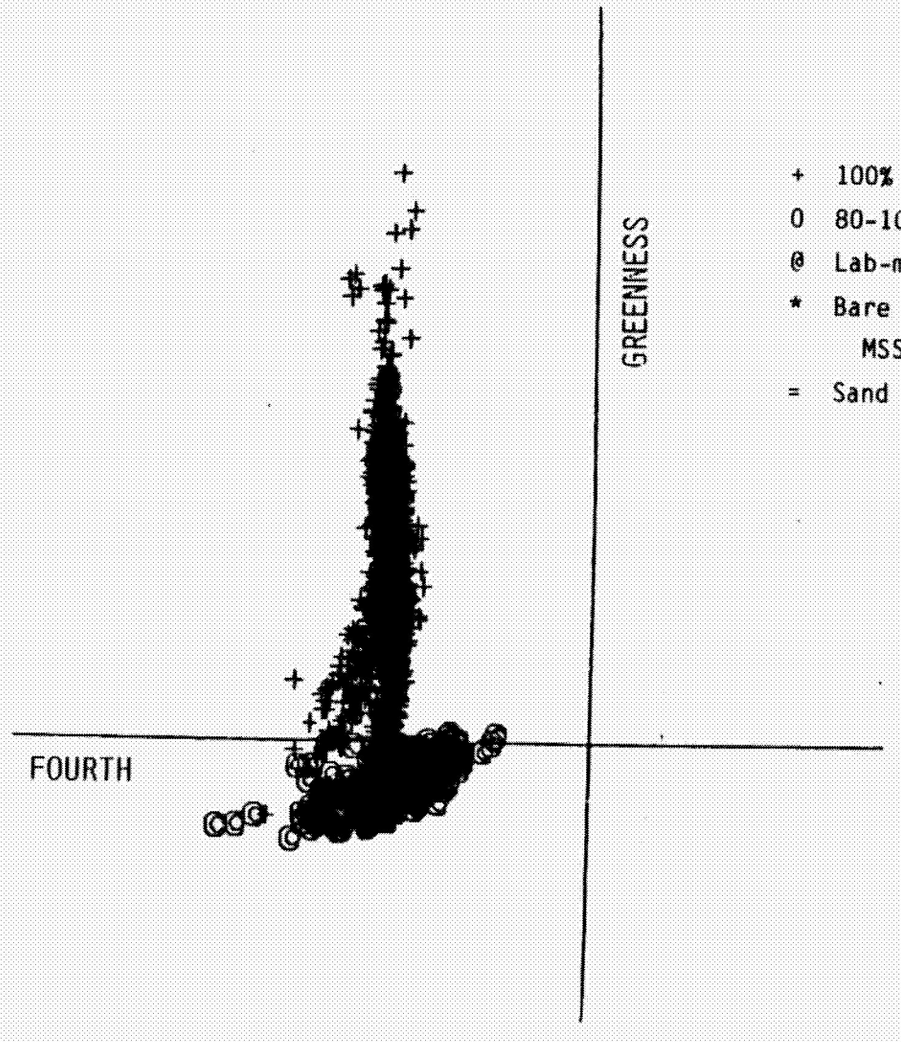
TM PRINCIPAL COMPONENTS (Continued)



KEY TO PLOTS

- \+ 100% Green Leaves, 90-100% Cover
- 0 80-100% Brown Leaves, 75-100% Cover
- @ Lab-measured Soils, Moist
- * Bare Soil Plots or < 10% Cover and MSS Greenness Below Threshold
- = Sand Data from Field Experiments

TM PRINCIPAL COMPONENTS (Continued)



KEY TO PLOTS

\+ 100% Green Leaves, 90-100% Cover

0 80-100% Brown Leaves, 75-100% Cover

@ Lab-measured Soils, Moist

* Bare Soil Plots or < 10% Cover and MSS Greenness Below Threshold

= Sand Data from Field Experiments

TENTATIVE CONCLUSIONS:

- METHODOLOGIES SUCCESSFULLY APPLIED TO LANDSAT MULTISPECTRAL DATA CAN PROBABLY BE APPLIED DIRECTLY TO THEMATIC MAPPER DATA AFTER RESCALING.

- THEMATIC MAPPER BANDS 1, 5, 6, AND 7 OFFER THE POTENTIAL FOR IMPROVED IDENTIFICATION OF LAND COVER CLASSES.

- EACH OF THE 6 NON-THERMAL BANDS SEEM TO CARRY USEFUL INFORMATION FOR THE PURPOSE OF AGRICULTURAL CLASSIFICATION.

- THERE ARE AT LEAST 4 INDEPENDENT DIMENSIONS OF INFORMATION IN THE NON-THERMAL BANDS.

VARIABLE SELECTION STUDIES/
EARLY SEASON ESTIMATOR IMPROVEMENTS

D. E. PHINNEY

VARIABLE SELECTION STUDIES/EARLY SEASON ESTIMATOR IMPROVEMENTS

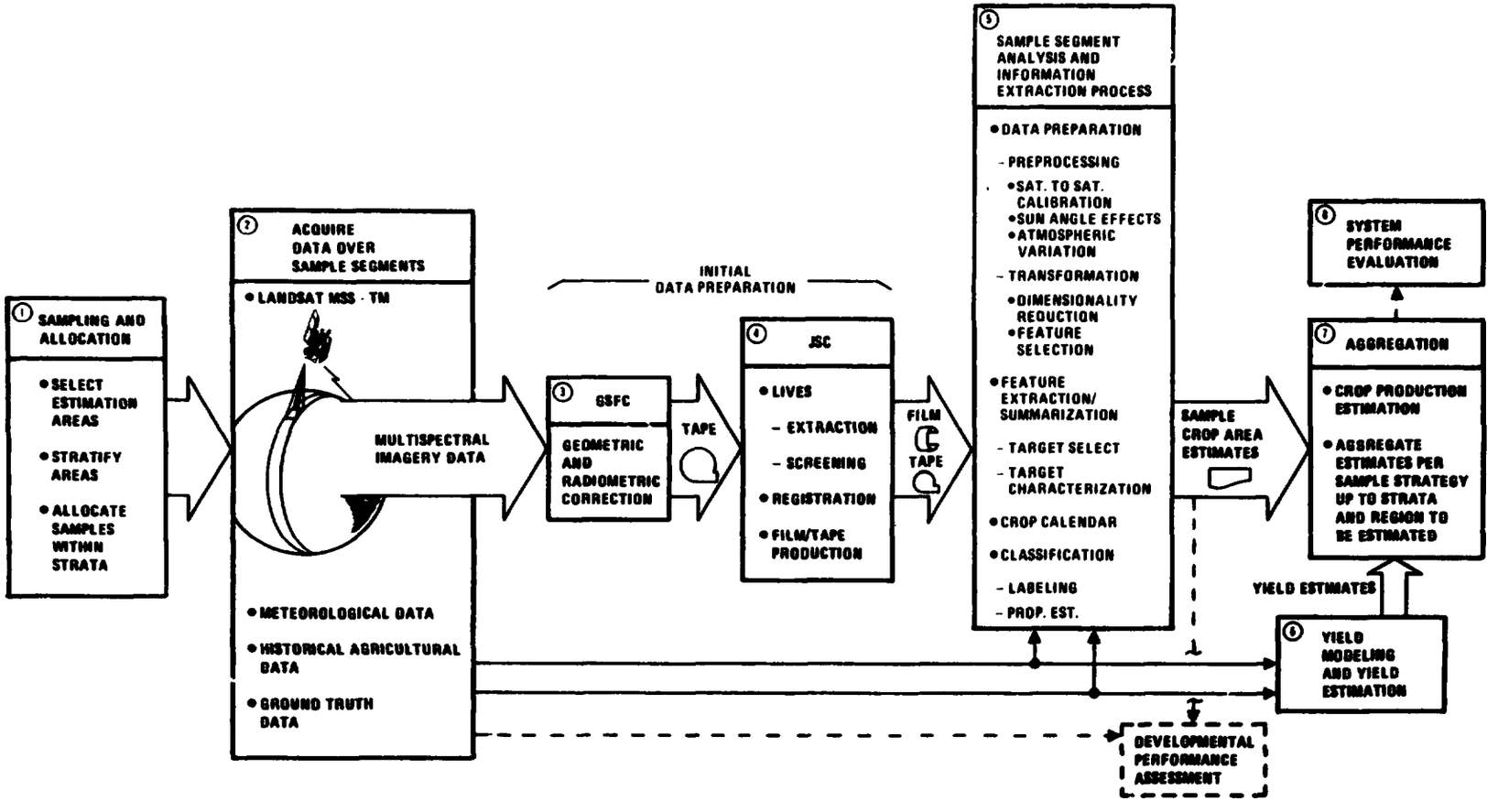
BACKGROUND:

- O DURING THE EARLY SEASON SPRING SMALL GRAINS PROPORTION ESTIMATION FEASIBILITY STUDY, SUBSTANTIAL DIFFERENCES IN ACCURACY WERE FOUND IN TRIALS USING TWO DIFFERENT VEGETATIVE MEASURES.

- O THE DIFFERENCES WERE ATTRIBUTED TO
  - -- INTRINSIC DIFFERENCES IN THE SPECTRAL TRANSFORMS
  - -- CHOICE OF PREPROCESSING OPTION
  - -- INTERACTION BETWEEN THE TWO EFFECTS

- O A STUDY WAS UNDERTAKEN TO UNDERSTAND THE SOURCES OF VARIATION OBSERVED DURING THE EARLY SEASON PROCEDURE DEVELOPMENT FOR PURPOSES OF
  - -- POTENTIAL IMPROVEMENTS IN THE EARLY SEASON PROCEDURE
  - -- GENERAL INSIGHT INTO THE SPECTRAL DATA PREPROCESSING/TRANSFORMATION PROBLEM FOR USE IN PROCEDURE DESIGN AND EVALUATION

INFORMATION EXTRACTION PROCESS



INFORMATION EXTRACTION FACTORS

- O INFORMATION EXTRACTION IS DEPENDENT UPON SPECTRAL SEPARABILITY BETWEEN A TARGET CLASS AND ITS POTENTIAL CONFUSION CLASSES.

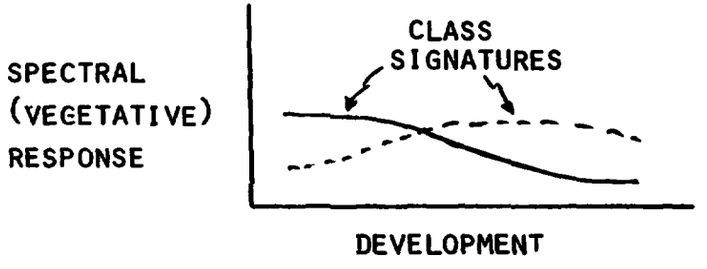
- O SPECTRAL SEPARABILITY IS A FUNCTION OF DIFFERENCES IN CLASS MEANS, THE MAGNITUDE OF CLASS VARIANCES, AND THE MULTITEMPORAL BEHAVIOR OF THE CLASS.

- O THE SUCCESS OF TRADITIONAL AREA ESTIMATION PROCEDURES IS DEPENDENT UPON SPECTRAL SEPARABILITY OF THE TARGET CLASS AND THE SEGMENT-TO-SEGMENT STABILITY OF PREDETERMINED DECISION RULES.

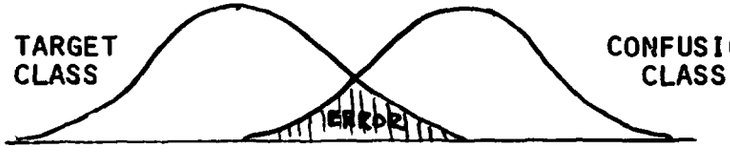
- O CAREFUL SELECTION OF CROP DEVELOPMENT SCALE AND THE PREPROCESSING, TRANSFORMATION, AND FEATURE EXTRACTION OPTIONS CAN MINIMIZE SCENE-TO-SCENE CLASS DIFFERENCES (SIGNATURE EXTENSION) AND MAXIMIZE AVERAGE CLASS-TO-CLASS DIFFERENCES IN A LOW DIMENSION FEATURE SPACE.

SPECTRAL CHARACTERISTICS ESTIMATION:

- ESTIMATES OF AVERAGE SPECTRAL CHARACTERISTICS (AND BETWEEN-SEGMENT VARIANCE) ARE CALCULATED FOR SELECTED GROUND COVER CLASSES USING DIGITAL FILTERING TECHNIQUES AT FREQUENT TIME INTERVALS THROUGHOUT THE SEASON.



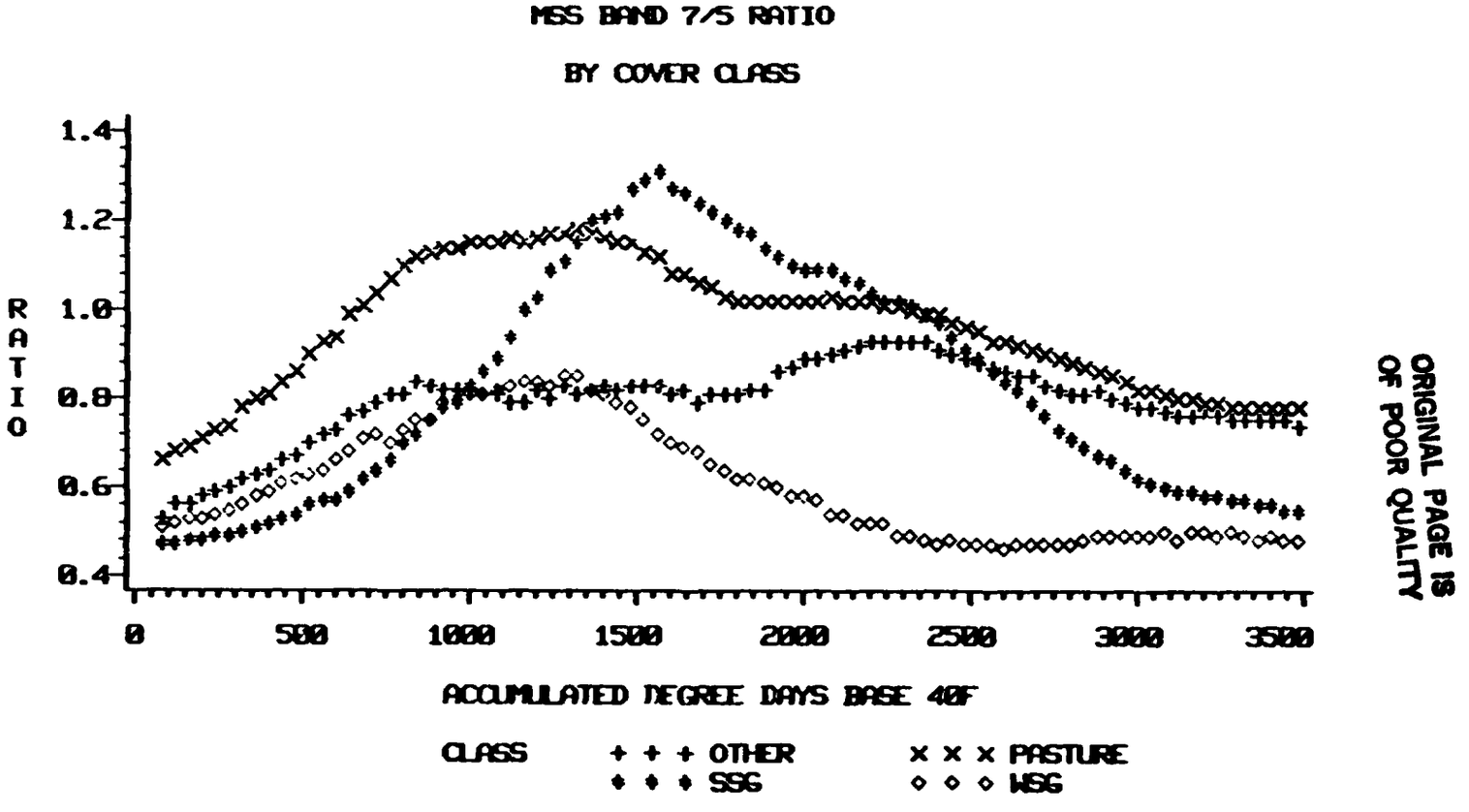
- ESTIMATES OF RELATIVE SEPARABILITY (SCENE-TO-SCENE) ARE CALCULATED BETWEEN A TARGET CLASS AND EACH POTENTIAL CONFUSION CLASS USING CLASS MEANS AND VARIANCES



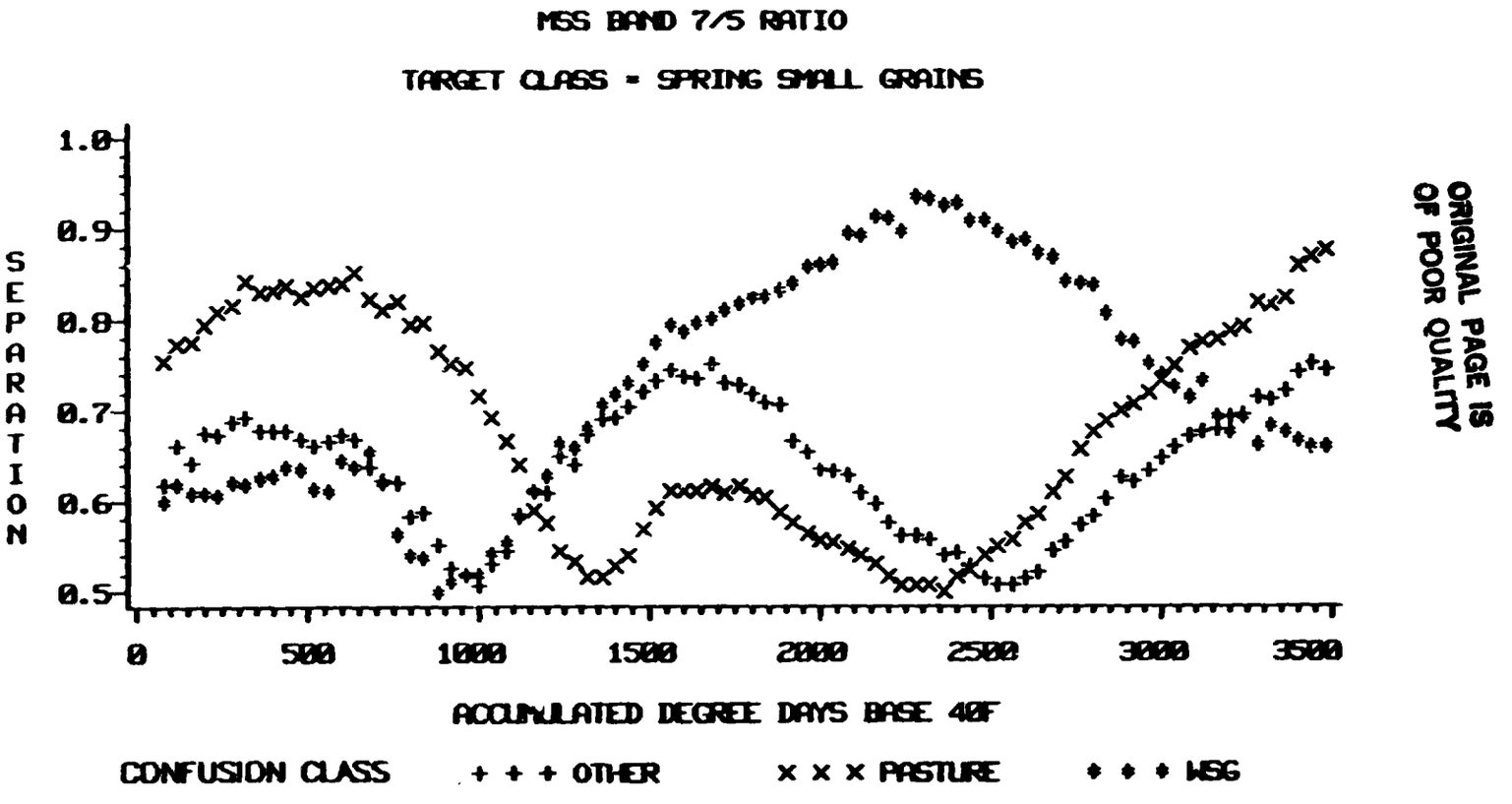
FOR EACH TIME INTERVAL

RELATIVE SEPARATION = (1-ERROR)

SPECTRAL CHARACTERISTICS



RELATIVE SPECTRAL SEPARATION



CASE STUDY DESIGN:

- FOR EACH CLOUD FREE ACQUISITION, SAMPLED SPECTRAL DATA (209 DOTS/ACQUISITION) WERE EXTRACTED AND SUMMARIZED FOR PURE GROUND TRUTH CLASSES AS FOLLOWS:

- WSG	WINTER SMALL GRAINS
- SSG	SPRING BARLEY OTHER SPRING GRAINS
- PASTURE	PASTURE
- OTHER	TREES SUMMER CROPS CORN SORGHUM SOYBEANS ALL OTHER

- FOR EACH ACQUISITION TWO PREPROCESSING OPTIONS WERE CONSIDERED
  - -- SATELLITE-TO-SATELLITE AND SUNANGLE CORRECTIONS "NON-NORMALIZED"
  - -- SCENE MEAN STANDARDIZATION "NORMALIZED"

CASE STUDY DESIGN (CONTINUED):

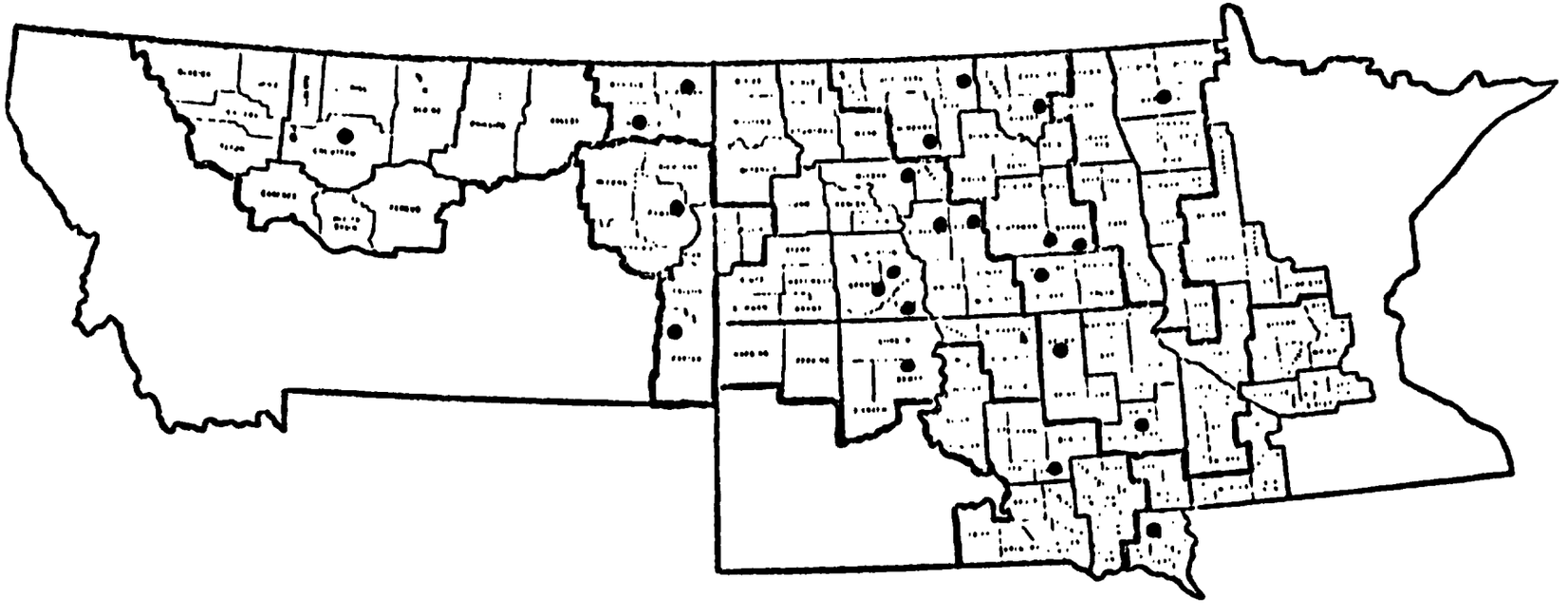
- FIVE VEGETATIVE MEASURES WERE EXAMINED
  - -- 4/5 CHANNEL RATIO "4/5"
  - -- 7/5 CHANNEL RATIO "7/5"
  - -- NORMALIZED DIFFERENCE "N-D"
  - -- KAUTH-THOMAS GREENNESS "K-T"
  - -- PRINCIPAL COMPONENT GREENNESS "P-C"

- TWO METHODS OF FEATURE SPACE SUMMARIZATION WERE CONSIDERED
  - -- AVERAGE OVER CROP GROUP "MEAN"
  - -- PERCENT OF CROP GROUP ABOVE A SPECIFIED THRESHOLD "PERCENT"

- THUS, TWENTY MEASURES WERE AVAILABLE FOR ANALYSIS IN A BALANCED DESIGN FOR EACH CROP GROUP

STUDY SEGMENTS

CROP YEAR 1976



LANDSAT BASED GREEN MEASURES

NAME	EQUATION	NOTATION
7/5 RATIO	MSS7 / MSS5	7/5
4/5 RATIO	MSS4 / MSS5	4/5
NORMALIZED DIFFERENCE	(MSS7-MSS5) / (MSS7+MSS5)	N-D
KAUTH-THOMAS GREENNESS	-.283 MSS4 - .660 MSS5 +.577 MSS6 + .388 MSS7	K-T
PRINCIPAL COMPONENT GREENNESS	-.477 MSS4 - .550 MSS5 +.416 MSS6 + .570 MSS7	P-C
KAUTH-THOMAS BRIGHTNESS	.332 MSS4 + .603 MSS5 +.676 MSS6 + .263 MSS7	
KAUTH-THOMAS YELLOWNESS	-.890 MSS4 + .428 MSS5 +.076 MSS6 - .041 MSS7	

EARLY SEASON CASE STUDY RESULTS SUMMARY

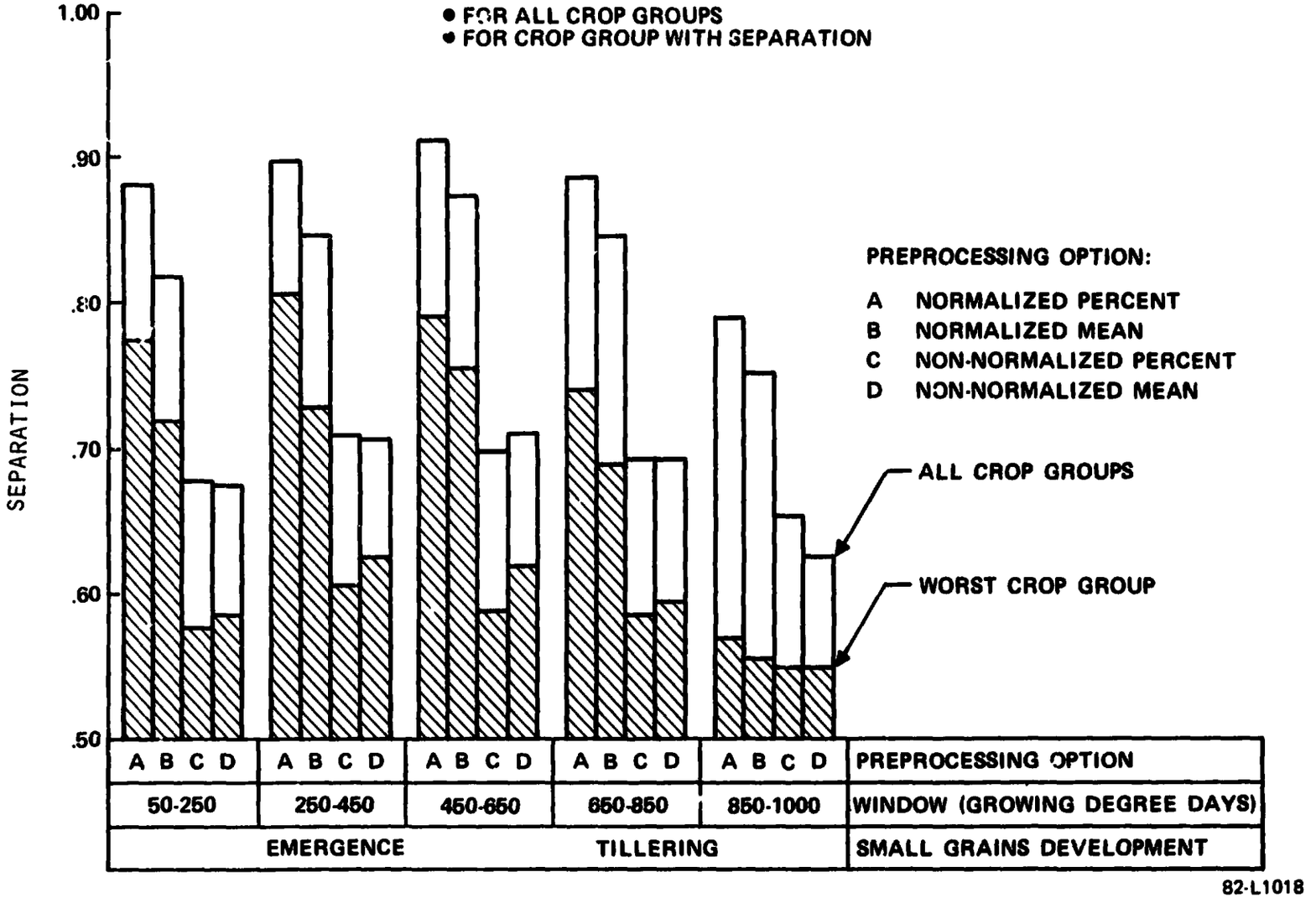
- A SIGNIFICANT DIFFERENCE WAS FOUND BETWEEN PREPROCESSING OPTIONS. THE DUNCAN RANGE TEST INDICATED THAT SCENE STANDARDIZATION WAS THE OPTION RESULTING IN THE BEST SEPARATION.

- A SIGNIFICANT DIFFERENCE WAS FOUND BETWEEN FEATURE SPACE SUMMARIZATION OPTIONS WITH THE MEASURES USING PERCENT ABOVE A SPECIFIED THRESHOLD PRODUCING THE BEST RESULTS.

- A SIGNIFICANT INTERACTION BETWEEN PREPROCESSING OPTION AND FEATURE SPACE SUMMARIZATION OPTION WAS FOUND. THE COMBINATION OF SCENE STANDARDIZATION AND THRESHOLDING PRODUCED THE BEST RESULTS.

- NO SIGNIFICANT DIFFERENCE WAS FOUND BETWEEN VEGETATIVE TRANSFORMS (EXCEPT FOR 4/5 RATIO)

EARLY SEASON SPRING SMALL GRAINS SEPARABILITY BY PREPROCESSING OPTION



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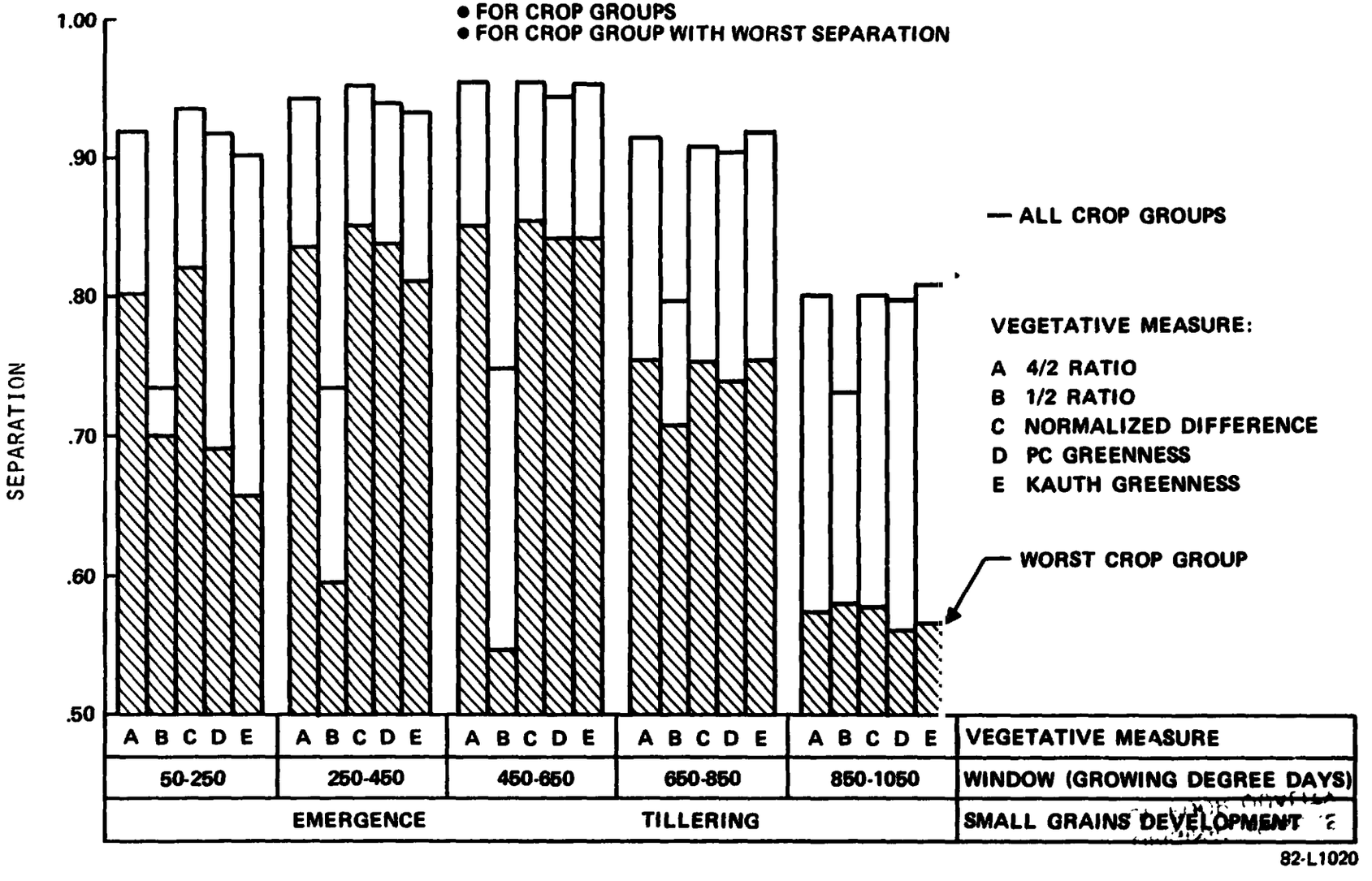
EARLY SEASON SPRING SMALL GRAINS SEPARABILITY BY VEGETATIVE MEASURE FOR THE NORMALIZED PERCENT PREPROCESSING OPTION



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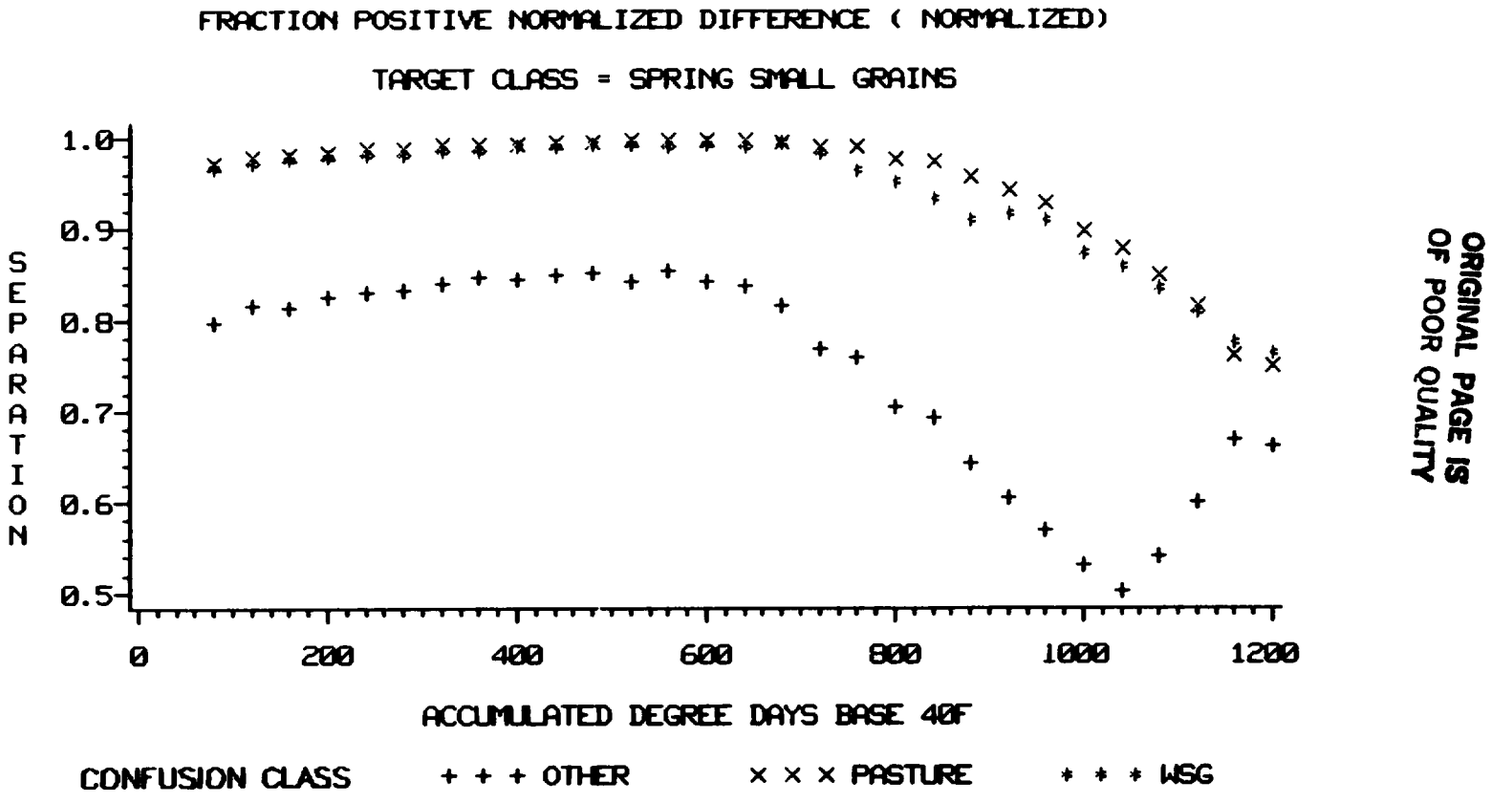
DUNCAN'S MULTIPLE RANGE TEST
EARLY SEASON WINDOW

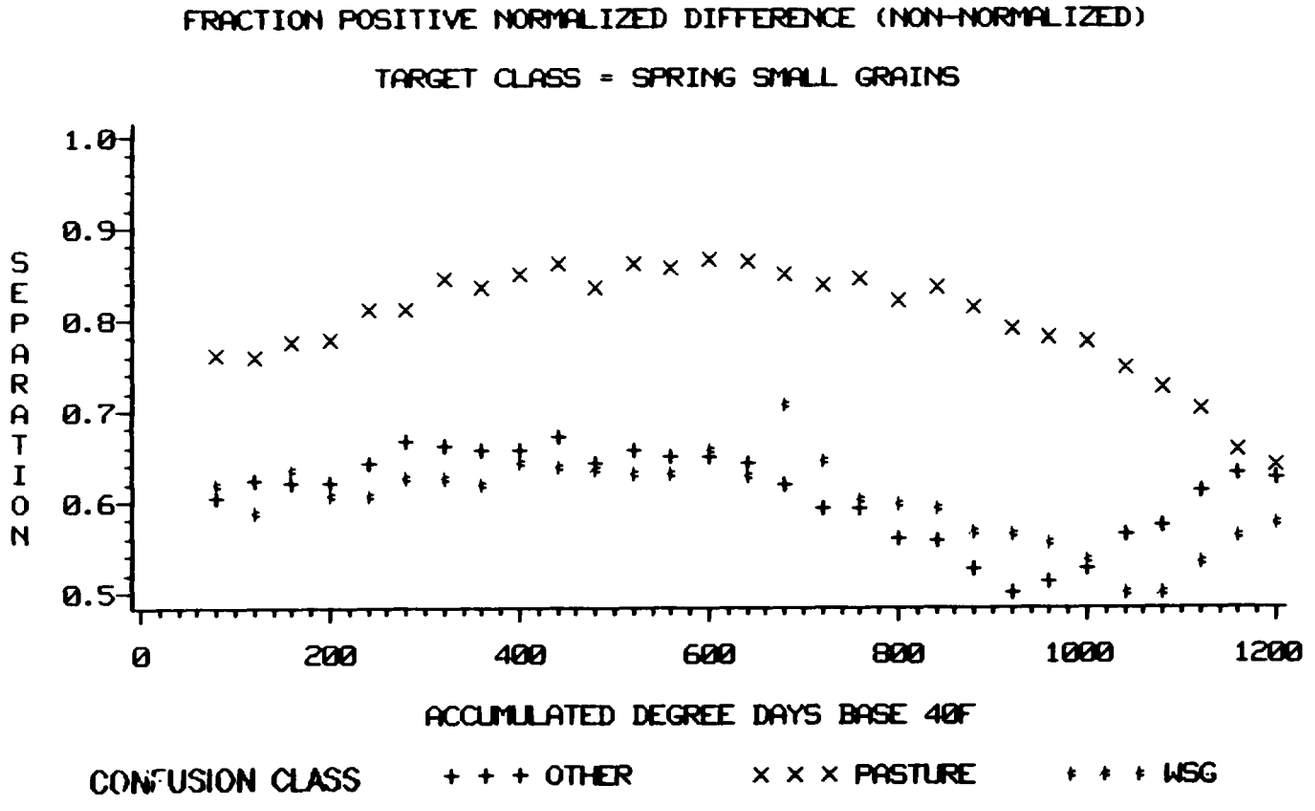
GROUPING	SEPARATION	N	VIN
A	0.943	27	N-D NORM PCT
A	0.938	27	4/2 NORM PCT
A	0.933	27	P-C NORM PCT
A	0.932	27	K-T NORM PCT
B	0.887	27	K-T NORM AVG
B	0.884	27	P-C NORM AVG
B	0.881	27	4/2 NORM AVG
C	0.870	27	N-D NORM AVG
D	0.755	27	K-T NON-NORM PCT
D	0.747	27	P-C NON-NORM PCT
E	0.734	27	1/2 NORM AVG
E	0.731	27	1/2 NORM PCT
E	0.724	27	K-T NON-NORM AVG
F	0.712	27	N-D NON-NORM AVG
F	0.712	27	4/2 NON-NORM AVG
G	0.692	27	P-C NON-NORM AVG
H	0.671	27	1/2 NON-NORM AVG
H	0.666	27	N-D NON-NORM PCT
H	0.666	27	4/2 NON-NORM PCT
H	0.665	27	1/2 NON-NORM PCT

SEPARATIONS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.
ALPHA LEVEL = .05 DF = 480

EARLY SEASON RELATIVE SPECTRAL SEPARATION



EARLY SEASON RELATIVE SPECTRAL SEPARATION



EARLY SEASON SPRING SMALL GRAINS PROPORTION ESTIMATION (SSG5/5A)

- EVALUATION OF PRELIMINARY TEST RESULTS FOR SSG5 BY THE ITD-USDA/FAS/FCCAD AD-HOC APPLICATIONS TEAM RESEARCH TEAM LED TO A RECOMMENDATION FOR EARLY IMPLEMENTATION.

- ANALYSIS OF THE VARIABLE SELECTION STUDY RESULTS (INCLUDING VAUABLES IN THE FCCAD DATA BASE) RESULTED IN MODIFICATION TO THEIR PREPROCESSING SOFTWARE AND CALCULATION OF A NEW SET OF VEGETATIVE INDICES.
  - -- SCENE MEAN STANDARDIZATION OVER GRID CELLS.
  - -- CALCULATION OF FRACTION POSITIVE NORMALIZED DIFFERENCE.

- AN EXPANDED EARLY SEASON TEST WAS CONDUCTED.
  - -- EVALUATE THE FCCAD CONFIGURATION
  - -- EVALUATE INCLUSION OF STRATA-LEVEL PRIOR INFORMATION.

- LINEAR MODEL

  THE OBSERVED AVERAGE SPECTRAL RESPONSE OF A SCENE MAY BE ESTIMATED AS A LINEAR COMBINATION OF THE MAJOR ELEMENTS IN THE SCENE.

$$B_I = \Sigma A_{IJ} X_J$$

SUBJECT TO

$$\Sigma X_J = 1$$

$$X_J \geq 0$$

WHERE

B_I -- THE FRACTION POSTIVE NORMALIZE DIFFERENCE (NORMALIZED) FOR THE SCENE FOR ACQUISITION DATE I

A_{IJ} -- THE EXPECTED FRACTION POSITIVE NORMALIZED DIFFERENCE (NORMALIZED) FOR CROP J ON ACQUISITION DATE I

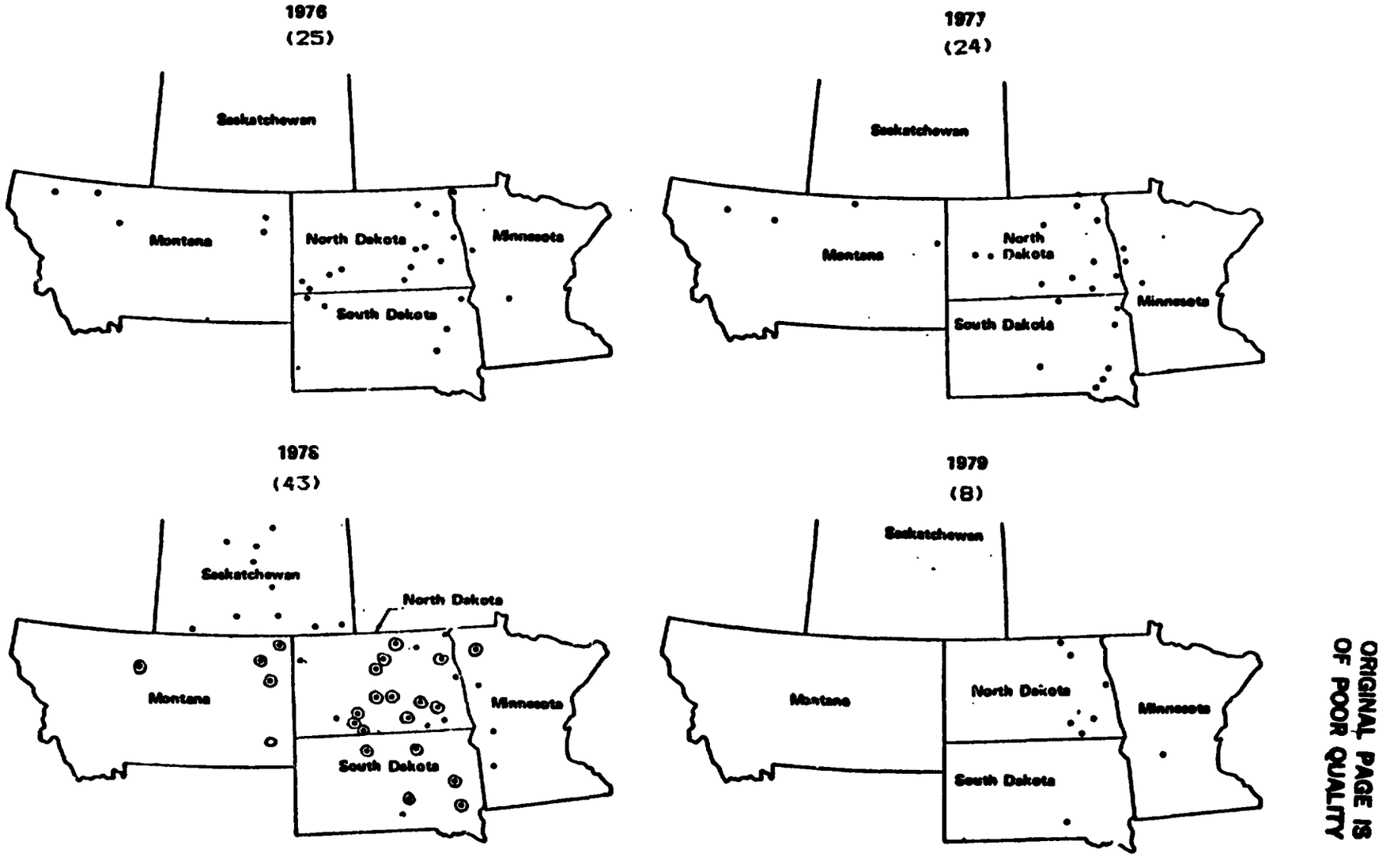
X_J -- THE PROPORTION OF CROP J

- CURRENT APPROACH
  - -- THE EARLY SEASON WINDOW IS BETWEEN 250 AND 600 ACCUMULATED GROWING DEGREE DAYS (BASE 40F)
  - -- THREE CROP CATEGORIES ARE CONSIDERED: PASTURE, SPRING SMALL GRAINS, AND OTHER
  - -- THE EXPECTED VALUES OF CROP SPECTRAL SIGNATURES WERE DERIVED FROM 23 CROP YEAR 1978 SAMPLE SEGMENTS
  - -- THE FRACTION POSITIVE NORMALIZED DIFFERENCE (SCENE STANDARDIZED) WAS USED AS THE VEGETATIVE INDEX
  - -- THE PSEUDO INVERSE IS USED TO SOLVE FOR X

$$X = A^{+}B + (I - A^{+}A)Z$$

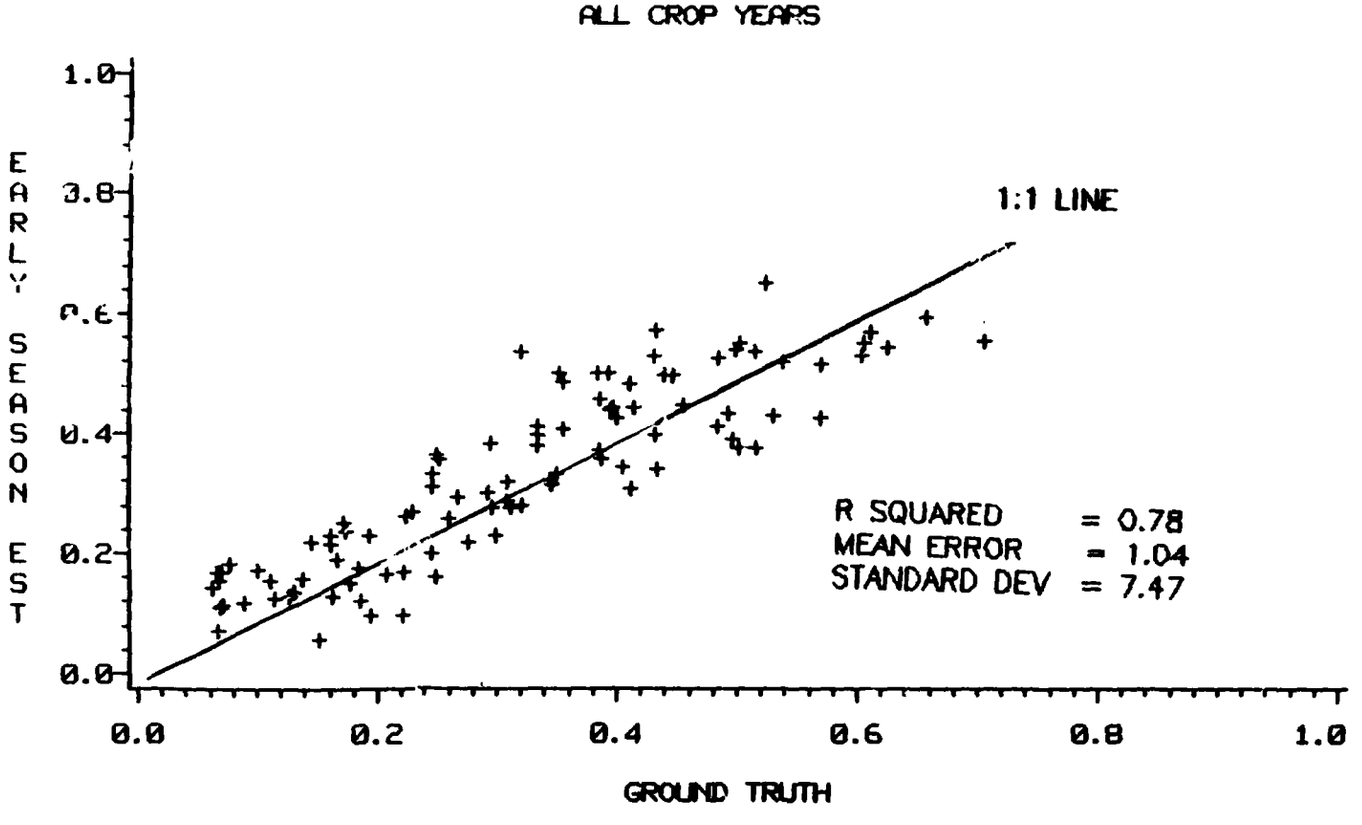
  - -- THE Z VECTOR IS USED TO INPUT PRIOR PROBABILITIES
  - -- UNITEMPORAL SOLUTIONS ARE AVERAGED WHEN MORE THAN ONE ACQUISITION FALLS IN THE EARLY SEASON WINDOW

SEGMENT LOCATIONS



O - DEVELOPMENTAL SEGMENTS

EARLY SEASON PROCEDURE (SSG5A)



PERFORMANCE OF SSG5A BY YEAR WITH SSG PRIORS

	1976	1977	1978	1979	OVERALL
MEAN ERROR	-1.12	.75	1.16	6.99*	1.04
STANDARD DEV	6.59	6.99	7.49	8.38	7.47
MEAN ABS ERROR	5.52	5.58	6.45	9.83	6.28
MEAN GT	31.12	30.99	32.03	34.11	31.72
REL MEAN ERROR	-3.60	2.42	3.62	23.42	3.28
SAMPLE SIZE	25	24	43	8	100
R SQUARED	.90	.77	.76	.80	.78
LL+	-3.29	-1.60	-.72	2.11	-.19
UL++	1.05	3.10	3.04	11.87	2.27

+ 90% CONFIDENCE LEVEL LOWER LIMIT ON TRUE BIAS
+ 90% CONFIDENCE LEVEL UPPER LIMIT ON TRUE BIAS
STATISTICALLY SIGNIFICANT AT THE 90% LEVEL

NOTE: SPRING SMALL GRAINS PRIORS BASED ON USDA CROP YEAR 1975 HISTORICAL STATISTICS APLLIED AT THE REFINED STRATA LEVEL

NOTE: 1979 LANDSAT DATA ACQUISITION SUBSTANTIALLY REDUCED BY NEED TO RETRO ORDER DATA

PERFORMANCE OF SSG4, SSG3C, SSG3B, AND HISTORICAL PROCEDURES BY YEAR

	ALL YEARS			1976			1977			1978			1979		
STATISTIC	SSG4	SSG3C	SSG3B	SSG4	SSG3C	SSG3B	SSG4	SSG3C	SSG3B	SSG4	SSG3C	SSG3B	SSG4	SSG3C	SSG3B
$\bar{e}$	-1.74*	1.55	3.01*	-4.48*	4.56*	5.62*	1.95	2.76	2.12	-2.21	-1.04	0.04	-2.14	3.80	7.71*
S_e	11.51	12.65	11.31	10.68	9.10	6.72	11.65	12.09	9.51	10.34	11.52	11.12	13.53	19.05	16.23
MAE	8.65	9.94	8.49	8.24	7.89	6.16	9.27	9.81	7.73	7.92	9.01	8.44	9.70	15.75	12.66
RME	-6.45	5.72	11.51	-19.45	16.70	24.10	7.62	10.04	8.20	-8.15	-3.90	0.15	-6.61	13.77	25.30
$\bar{p}$	26.96	27.10	26.16	23.03	27.31	23.32	25.59	27.48	25.85	27.11	26.66	26.04	32.38	27.60	30.47
n	169	112	144	36	21	30	38	25	37	61	50	53	34	16	24
r^2	-	-	-	.73	.85	.91	.61	.50	.71	.66	.62	.66	.41	.18	.35
LL+	-3.20	-0.43	1.45	-7.49	1.13	3.54	-1.24	-1.38	-0.52	-4.42	-3.77	-2.52	-6.07	-4.55	2.03
UL++	-0.28	3.53	4.57	-1.47	7.99	7.70	6.14	6.90	4.76	0.00	1.69	2.60	1.79	12.15	13.39

			U.S.	S.K.	
$\bar{e}$	-5.51*	-6.10*	-4.0*	-2.9	-3.5*
S_e	8.52	5.40	7.40	7.36	6.0
RME	-24.51	-17.48	-13.94	-6.8	-11.9
n	35	45	38	15	35
LL+	-7.9	-7.4	-6.0	6.3	-5.2
UL++	-3.1	-4.8	-2.0	0.5	-1.8
	LACIE Phase II	LACIE Phase III	LACIE TY		1980 SSG Exploratory

+ 90% confidence level lower limit on true bias.
++ 90% confidence level upper limit on true bias.
* Statistically significant at 90% level.

EARLY SEASON CONCLUSIONS AND RESEARCH DIRECTIONS

- AN ACCURATE, EFFICIENT, AUTOMATED EARLY SEASON SPRING SMALL GRAINS PROPORTION ESTIMATOR HAS BEEN ACHIEVED AND HAS BEEN TRANSFERED TO FCCAD
  - -- ESTIMATES PRIOR TO TILLERING
  - -- LOW DATA PROCESSING/PREPROCESSING REQUIREMENTS
  - -- NO REGISTRATION REQUIREMENT

- EARLY SEASON SPRING SMALL GRAINS ESTIMATORS COMBINING LOW BIASES OF BEST END-OF-SEASON AUTOMATED ESTIMATORS WITH VARIANCES NEARLY AS LOW AS BEST END-OF-SEASON MANUAL PROCEDURES APPEAR POSSIBLE

- FUTURE RESEARCH INCLUDES
  - -- EXTENSION TO THROUGH-THE-SEASON ESTIMATION
  - -- ALTERNATE MODEL FORMULATIONS
  - -- EXTENSION TO MULTIPLE LAND COVER CLASSES
  - -- APPLICATION TO YEAR-TO-YEAR CHANGE ESTIMATION

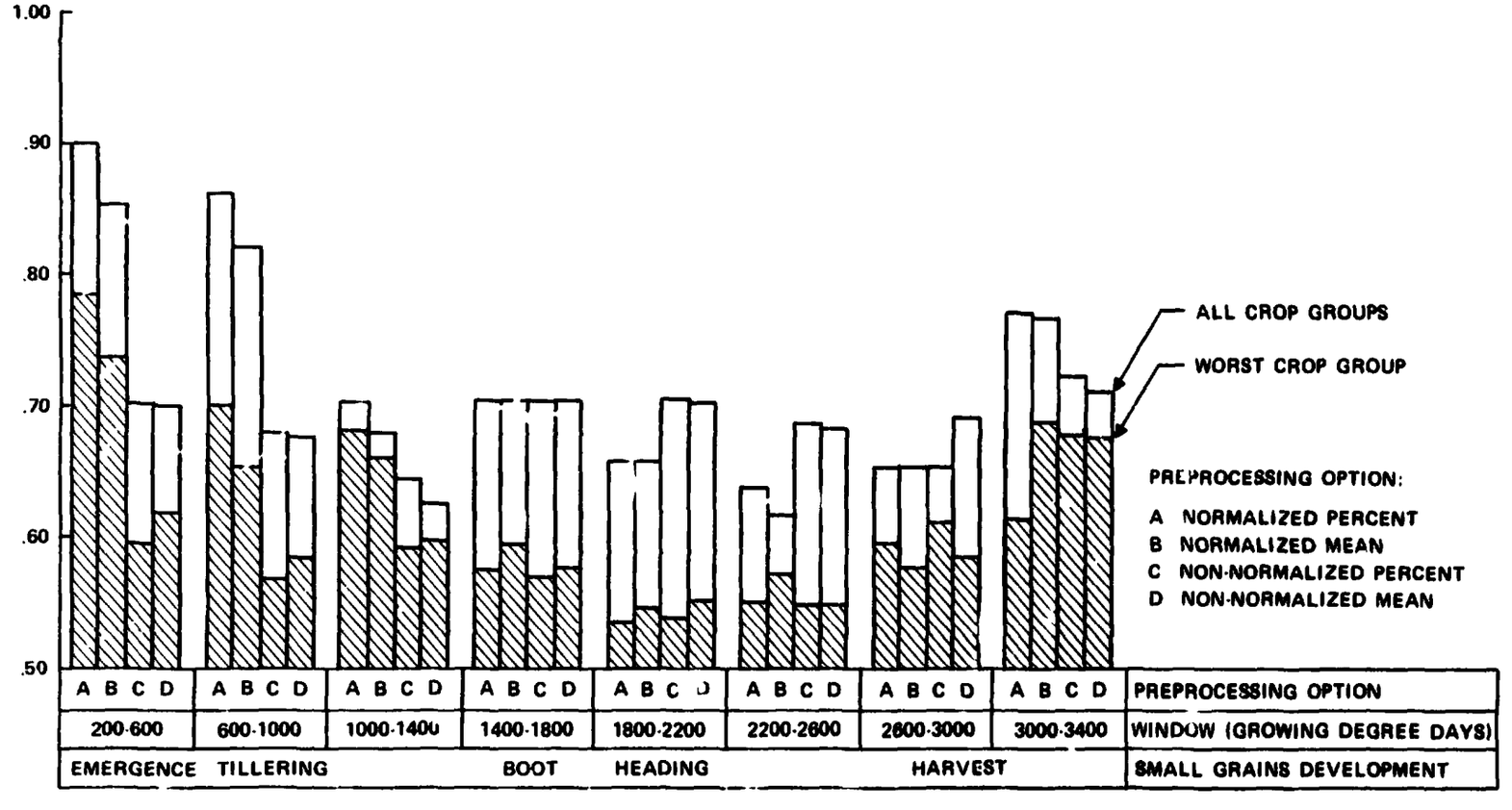
THROUGH SEASON SPRING SMALL GRAINS CASE STUDY RESULTS SUMMARY

- EARLY AND LATE SEASON RESULTS SIGNIFICANTLY FAVOR THE SCENE STANDARDIZATION OPTION. MIDSEASON TIME PERIODS SHOW NO SIGNIFICANT DIFFERENCES BETWEEN OPTIONS.

- SIMILAR RESULTS ARE OBSERVED FOR THE FEATURE SPACE SUMMARIZATION OPTIONS. EARLY AND LATE SEASON TIME PERIOD SEPARATIONS ARE BEST WITH THE PERCENTAGE OPTION WITH NO SIGNIFICANT DIFFERENCES IN THE MIDSEASON.

SPRING SMALL GRAINS SEPARABILITY BY PREPROCESSING OPTION

- FOR CROP GROUPS
- FOR CROP GROUP WITH WORST SEPARATION



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BARLEY/OTHER SPRING SMALL GRAINS CASE STUDY SUMMARY

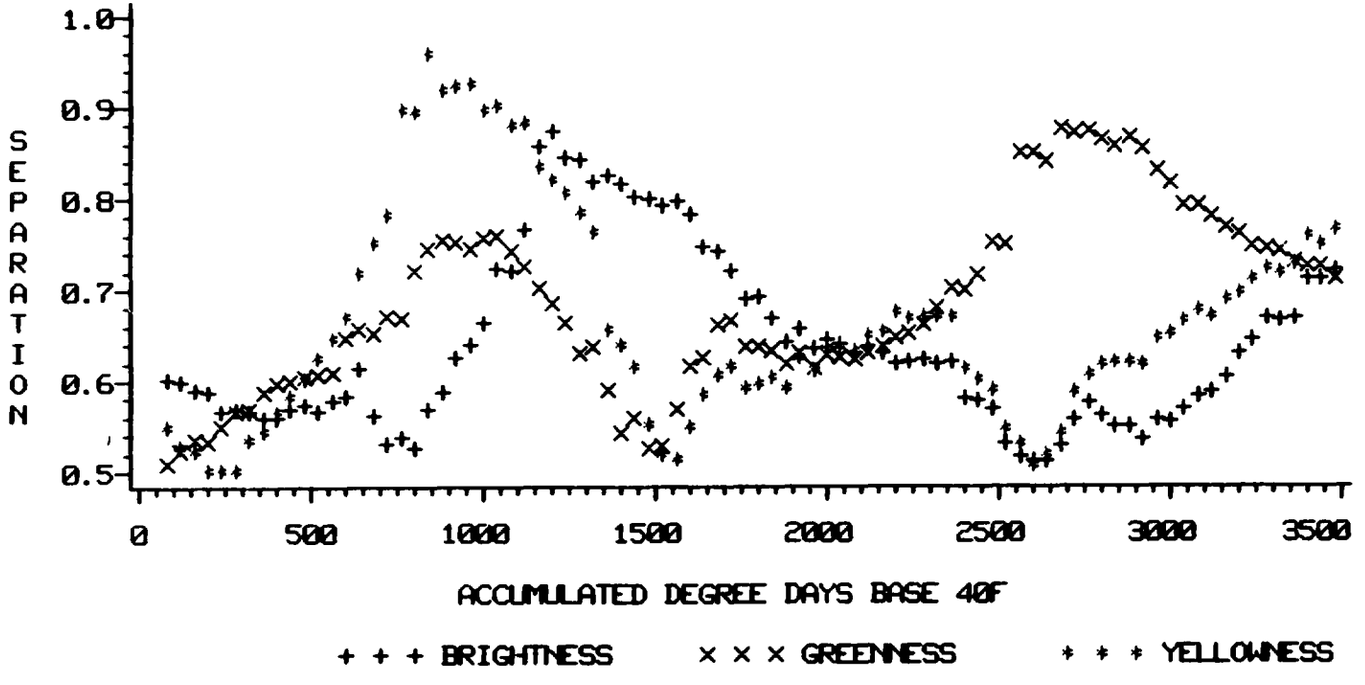
- AT ALL TIME PERIODS EXAMINED, THE COMBINATION OF SCENE STANDARDIZATION FOR PREPROCESSING AND PERCENT ABOVE A THRESHOLD FOR FEATURE SUMMARIZATION RESULTED IN THE BEST SCENE-TO-SCENE SEPARABILITY.

- IMPORTANT EVIDENCE OF MULTITEMPORAL, MULTIVARIATE SEPARATIONS WERE OBSERVED WHICH MAY BE THE BASIS FOR A SUCCESSFUL BARLEY SEPARATION PROCEDURE.

BARLEY / OTHER SPRING SMALL GRAINS RELATIVE SPECTRAL SEPARATION

KAUTH-THOMAS TRANSFORM (SCENE NORMALIZED)

TARGET CLASS = SPRING SMALL GRAINS



CONCLUSIONS:

- AN EFFICIENT, OBJECTIVE DESIGN TOOL HAS BEEN DEVELOPED FOR
  - -- EVALUATION OF PROPOSED PREPROCESSING METHODOLOGIES
  - -- SELECTION OF VEGETATIVE TRANSFORM
  - -- CROP CALENDAR EVALUATION
  - -- BIOWINDOW SELECTION
  - -- DETERMINATION OF FEASIBILITY FOR SEPARATION OF SPECIFIC GROUND COVER CLASSES.

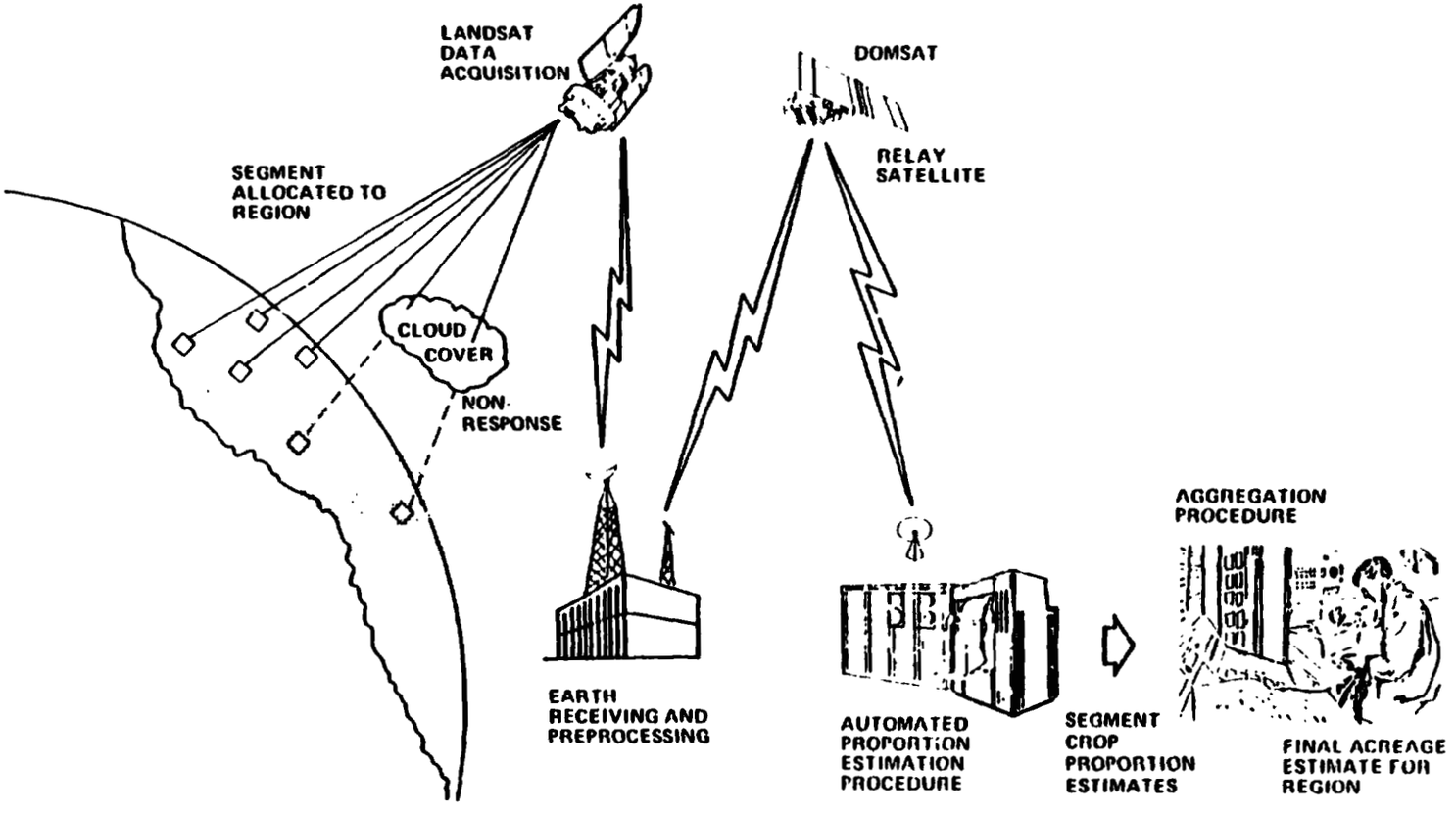
- FUTURE EFFORTS WILL FOCUS ON
  - -- EXPANDED DATA BASES FOR MULTIPLE GROUND COVER CLASSES
  - -- MEASURES OF MULTIVARIATE, MULTI-COVER CLASS RELATIVE SEPARATION (PARAMETRIC AND NONPARAMETRIC)

THE AGRICULTURAL INFORMATION SYSTEM SIMULATOR

DETERMINATION OF LANDSAT ORBITAL EFFECTS ON LARGE AREA ESTIMATE BIAS AND VARIANCE

T. BAKER

SOURCES OF ERROR IN A SATELLITE-BASED CROP ACREAGE ESTIMATION SYSTEM



	SAMPLE DESIGN	DATA COLLECTION	SEGMENT PROPORTION ESTIMATION	AGGREGATION TO REGIONAL ACREAGE ESTIMATE
CONTRIBUTION TO BIAS AND VARIANCE	• STRATIFICATION • SEGMENT ALLOCATION • SAMPLING VARIANCE	• NONRESPONSE DUE TO • CLOUD COVER • REGISTRATION PROBLEMS • MECHANICAL FAILURES	• CROP MIX • INADEQUATE CROP STAGE MODELS • CROP LABELING VARIANCE • FIELD SIZE	• QUALITY OF HISTORICAL DATA • AGGREGATION TECHNIQUE

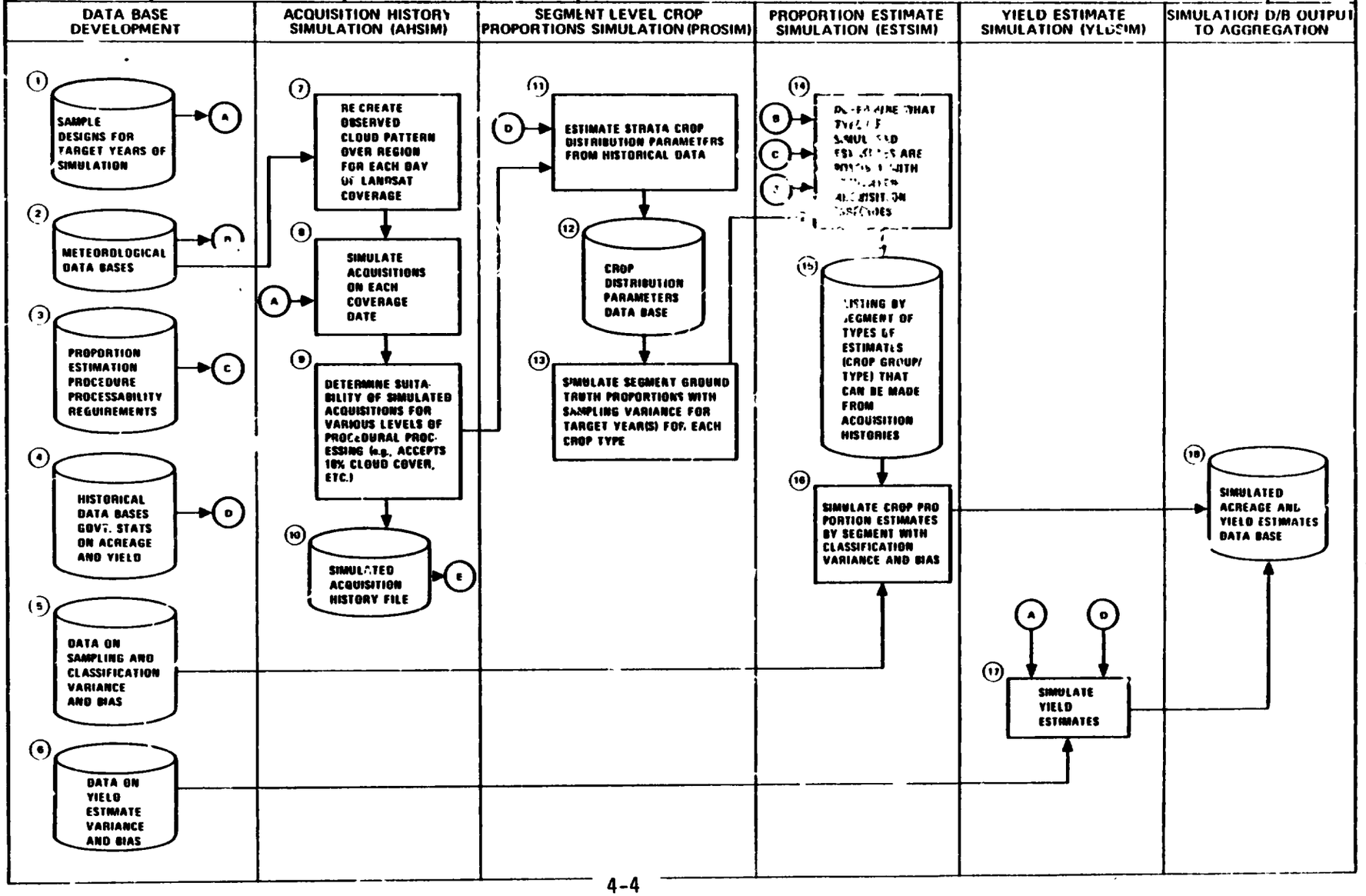
RATIONALE FOR THE AGRICULTURAL INFORMATION SYSTEM SIMULATOR (AgSIM)

- O INVESTIGATION OF LARGE AREA ESTIMATION SYSTEM CHARACTERISTICS VIA OTHER MEANS IS INEFFICIENT/INFEASIBLE.
  - + THEORETICAL (MATHEMATICAL MODEL) SYSTEM REPRESENTATIONS ARE INADEQUATE AND INFLEXIBLE
  - + LANDSAT DATA ARE NOT AVAILABLE TO SUPPORT EVALUATION UNDER THE FULL RANGE OF CONDITIONS OF INTEREST
- O THE SIMULATOR PROVIDES REALISTIC DATA FOR USE IN SYSTEM EVALUATIONS
  - + DATA MAY BE GENERATED
    - ++ IN UNLIMITED AMOUNTS UNDER CONTROLLED CONSTANT CONDITIONS
    - ++ OVER A BROAD RANGE OF OPERATIONALLY INTERESTING CONDITIONS
  - + SYSTEM EVALUATION CAPABILITIES INCLUDE
    - ++ DETERMINING THE RESPONSE TO CHANGE IN BASIC CHARACTERISTICS
    - ++ DETERMINING WHETHER STATED GOALS ARE ATTAINABLE WITH CURRENT TECHNOLOGIES
    - ++ SETTING REQUIREMENTS FOR NEW TECHNOLOGIES

SYSTEM EVALUATION CAPABILITY EXAMPLES

- ABILITY TO EVALUATE SENSITIVITY OF LARGE AREA ESTIMATE TO:
  - + CLOUD COVER MULTIPLE YEARS
  - + SAMPLE ALLOCATION
  - + PROPORTION ESTIMATOR BIAS AND VARIANCE
  - + ORBIT FREQUENCY AND PHASING
  - + SENSOR FIELD OF VIEW
  - + VARIOUS AGGREGATION MODULES
  - + QUALITY OF HISTORICAL DATA

LEVEL	TYPE	DESIGNATOR				PROCEDURE NAME	DATE
		TECH.	SIM.	#	VAR.		
COMP.	PERFORM. EVAL.	AG	SIM	1		AGRICULTURAL INFORMATION SYSTEM SIMULATION	8/82

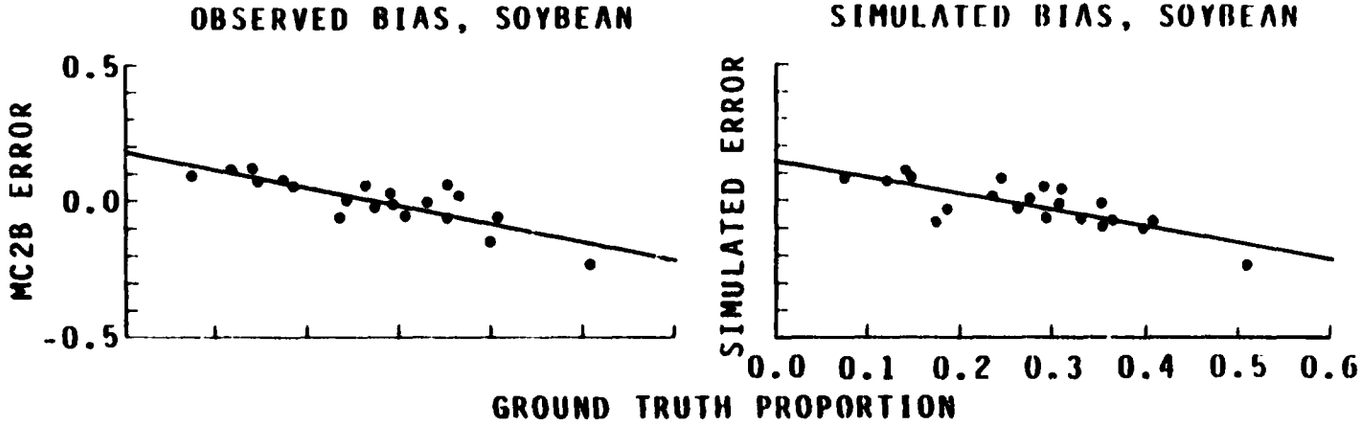


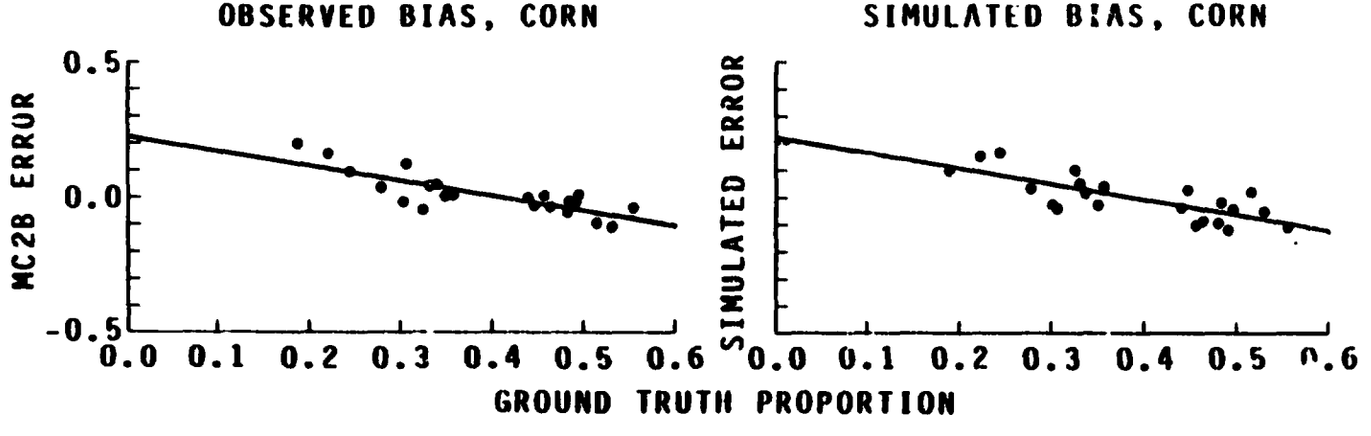
AGRICULTURAL INFORMATION SYSTEM SIMULATOR DESIGN CRITERIA

- REALISTIC MODELS
  - ++ INTERACTIONS BETWEEN THE TEMPORAL AND SPATIAL CLOUD COVER PATTERNS AND SATELLITE ORBIT CYCLE (AHSIM)
  - ++ SAMPLING ERROR (PROSIM)
  - ++ CLASSIFICATION ERROR (ESTSIM)
  - ++ AGGREGATION ERROR (EXISTING TECHNOLOGY)
- EASE IN SIMULATING FACTORS AFFECTING THE VARIANCE AND BIAS OF LARGE AREA CROP ESTIMATES
- MODULAR - SOFTWARE COMPONENTS OF THE SYSTEM CORRESPOND TO COMPONENTS OF THE LARGE AREA ESTIMATION SYSTEM
  - ++ ADAPTABLE TO SYSTEM CHANGES
  - ++ FLEXIBLE USAGE

C-2

EXAMPLE: AGSIM CLASSIFICATION ERROR SIMULATION (EST SIM)





APPLICATIONS OF THE AGRICULTURAL INFORMATION SYSTEM SIMULATOR

- EVALUATION OF THE EFFECT OF THE LANDSAT-4 16-DAY ORBIT CYCLE ON:
  - ++ NUMBER OF ACQUISITIONS PER SEGMENT
  - ++ SEGMENT PROCESSABILITY RATES
  - ++ LARGE AREA ESTIMATES BIAS AND VARIANCE
- PLANNING FOR FUTURE STUDIES IS UNDERWAY. POSSIBLE STUDY QUESTIONS INCLUDE:
  - ++ UNDER WHAT CONDITIONS CAN AN ACCEPTABLE ESTIMATE OF FOREIGN CROP AREA BE OBTAINED?
  - ++ DO CURRENT ESTIMATION TECHNOLOGIES MEET THESE CRITERIA?
  - ++ WHAT IS THE MAXIMUM ERROR THAT CAN BE TOLERATED IN EACH COMPONENT OF THE ESTIMATION SYSTEM?

EVALUATION OF THE EFFECT OF THE LANDSAT-4 ORBIT ON LARGE AREA ESTIMATES BIAS AND VARIANCE

OBJECTIVE: DETERMINE WHETHER THE 16-DAY CYCLE OF LANDSAT-4 AFFECTS THE BIAS AND VARIANCE OF LARGE AREA ESTIMATES

- MORE FREQUENT COVERAGE - 16-DAY CYCLES VERSUS 18-DAY CYCLES FOR PREVIOUS LANDSATS
- LESS OVERLAP BETWEEN ADJACENT TRACKS - 16% OVERLAP FOR LANDSAT-2 VERSUS 8% OVERLAP FOR LANDSAT-4 (AT THE EQUATOR)

CONCLUSIONS:

- NUMBER OF ACQUISITIONS PER SEGMENT
  - + AVERAGE IS THE SAME
  - + VARIANCE IS HIGHER FOR LANDSAT-2
- PROCESSING RATE
  - + SIGNIFICANTLY BETTER STATISTICALLY FOR LANDSAT-4
  - + OBSERVED MAGNITUDE OF IMPROVEMENT WAS DIMINISHED BY A TEST SAMPLE ALLOCATION THAT (BY CHANCE) FAVORED LANDSAT-2
- PERFORMANCE OF LARGE AREA ESTIMATE
  - + BIASES AND VARIANCES UNAFFECTED
- A SIGNIFICANT INTERACTION BETWEEN SATELLITE ORBIT CYCLE AND WEATHER WAS OBSERVED

EVALUATION OF THE EFFECT OF THE LANDSAT-4 ORBIT ON LARGE AREA ESTIMATE BIAS AND VARIANCE (CONTINUED)

APPROACH:

COMPARE AVERAGE NUMBER OF ACQUISITIONS PER SEGMENT, AVERAGE PROCESSING RATE, AND LARGE AREA ESTIMATE BIAS AND VARIANCE

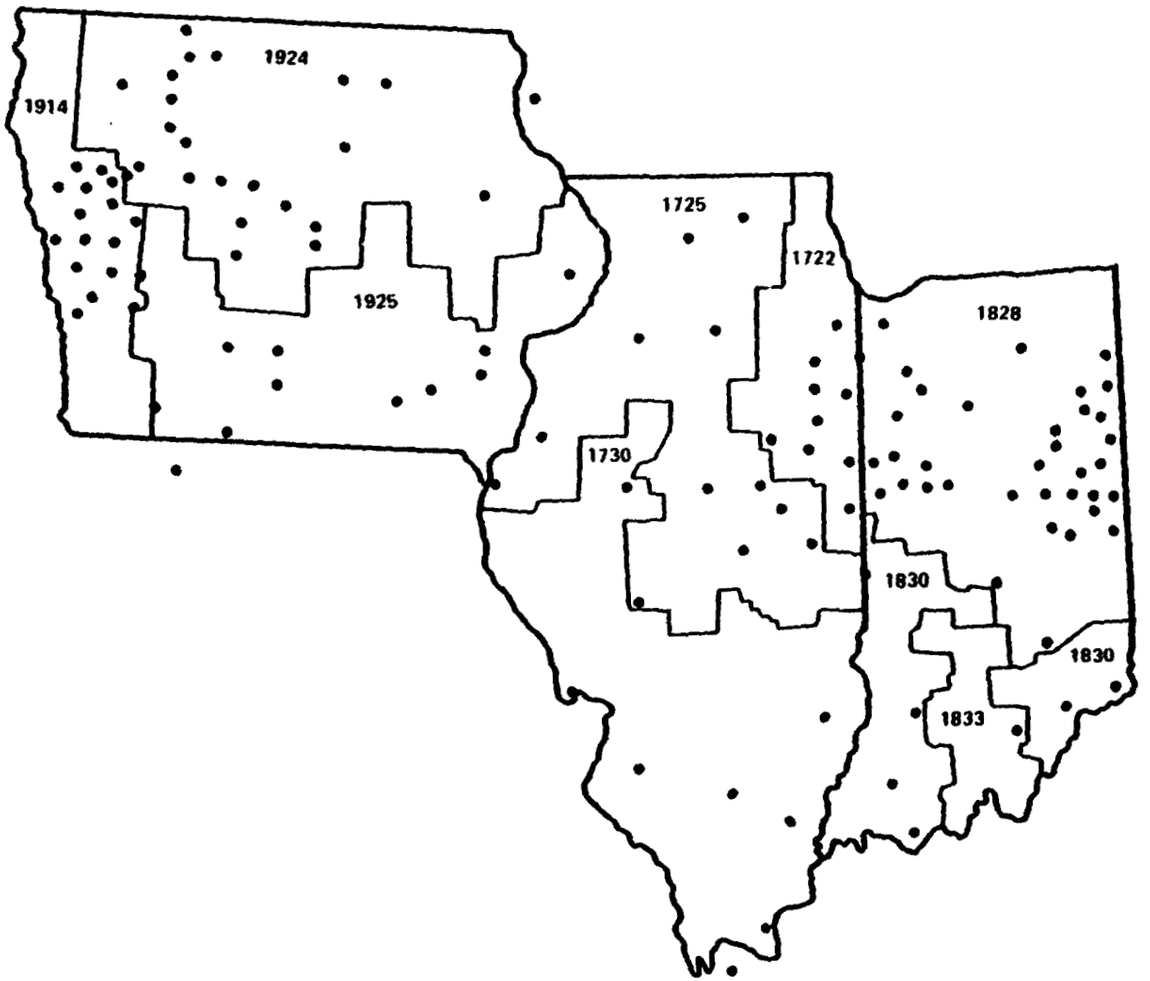
SCOPE:

- 180 SEGMENTS IN ILLINOIS, IOWA, AND INDIANA
- 1975 CLOUD COVER DATA
- 10 REPLICATIONS
- MC2 ACQUISITION SELECTION LOGIC

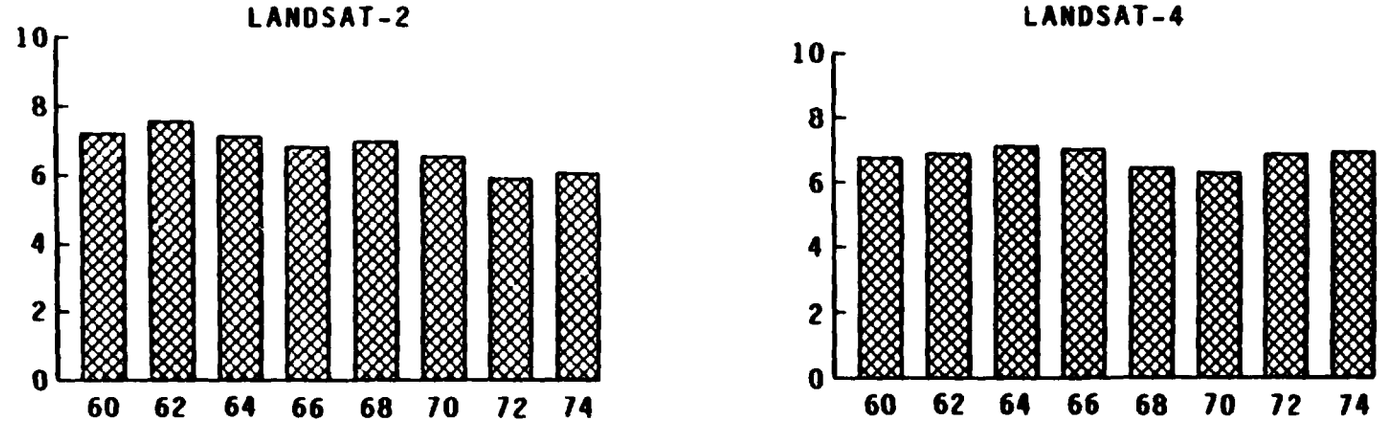
METHODOLOGY:

ANALYSIS OF VARIANCE ON VARIABLES OF INTEREST

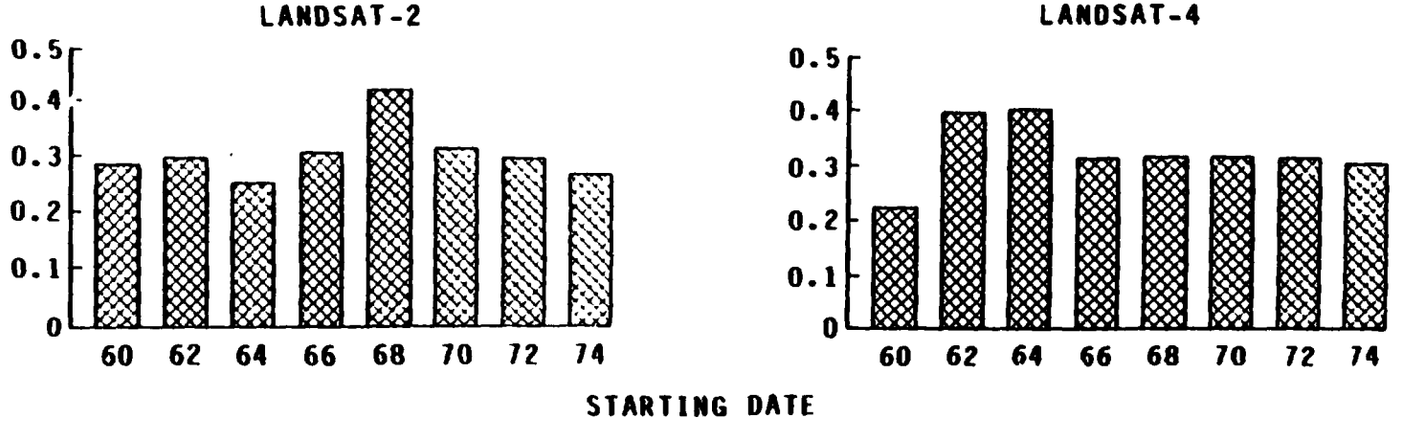
LANDSAT-4 VERSUS LANDSAT-2 ORBITS:
SEGMENT ALLOCATION AND STRATA USED FOR AGGREGATION



AVERAGE NUMBER OF ACQUISITIONS PER SEGMENT



MC2 PROCESSING RATE



ANALYSIS OF VARIANCE TABLES

AVERAGE NUMBER OF ACQUISITIONS PER SEGMENT

SOURCE	DF	F VALUE	P VALUE	R^2
MODEL	87	15.81	.0001	.95
ERROR	72			
SATELLITE	1	.57	.45	
STARTING DATE	14	94.87	.0001	
REPLICATIONS	72	.65	.97	

MC2 PROCESSING RATE

SOURCE	DF	F VALUE	P VALUE	R^2
MODEL	87	6.31	.0001	.88
ERROR	72			
SATELLITE	1	5.77	.0189	
STARTING DATE	14	34.33	.0001	
REPLICATIONS	72	.87	.72	

BIAS OF LARGE AREA ESTIMATE

SOURCE	DF	F VALUE	P VALUE	R^2
MODEL	87	1.62	.47	.55
ERROR	72			
SATELLITE	1	.05	.81	
STARTING DATE	14	1.02	.42	
REPLICATIONS	72	.96	.56	

SUMMARY

- THE AGRICULTURAL INFORMATION SYSTEM SIMULATOR IS A VALUABLE TOOL FOR USE IN DESIGNING AND EVALUATING LARGE AREA CROP ESTIMATION SYSTEMS
  - ++ THE REQUIRED SOFTWARE IS READY FOR USE
  - ++ THE FIT OF THE MODELS TO OBSERVED DATA HAS BEEN TESTED AND SHOWN TO BE REALISTIC
  - ++ THE COST FOR AGSIM USE IS VERY LOW
- CURRENT AND PLANNED SIMULATION STUDIES ADDRESS QUESTIONS WHICH ARE MOST EASILY AND MOST ACCURATLY ANSWERED USING SIMULATION TECHNOLOGY

LARGE UNIT PROPORTION ESTIMATION

H. G. SMITH

OBJECTIVE

- THE DEVELOPMENT OF A FULLY AUTOMATED CROP INVENTORY TECHNOLOGY THAT:
  - IS AMENABLE TO THE CURRENT FCCAD ENVIRONMENT
    - PRECISE REGISTRATION NOT REQUIRED
    - USES SKIP SAMPLED FULL-FRAME DATA
  - SIGNIFICANTLY REDUCES THE COST AND INCREASES THE EFFICIENCY OF PROCESSING LARGE DATA SETS

METHODOLOGY

- FULL SCENE SAMPLING (5X5)
- 2 ACQUISITION REGISTRATION (SIMPLE OFFSET SUFFICIENT)
  - + REQUIREMENT
    - ++ FIRST - 50% WHEAT HEADED (~600 GDD 50-86)
    - ++ SECOND - 100% WHEAT HARVESTED (45-60 DAYS AFTER THE FIRST)
- SCENE NORMALIZATION
- DATA TRANSFORMATION
  - + CUBIC COLOR SPACE (HUE, VALUE, AND CHROMA) - FALSE COLOR IR ANALOG
- DATA SCREENING
  - + CLOUDS, CLOUD SHADOW, WATER, AND BAD DATA
- SPATIAL CLUSTERING FOR LABELING TARGET DEFINITION
  - + BY-ACQUISITION SPATIAL CHAINING OF "VEGETATED" AND "NON-VEGETATED" PIXELS INTO AGGLOMERATIONS OF FIELDS (AGRICULTURAL ZONES)
  - + INTERSECTION OF BY-ACQUISITION AGGLOMERATIONS TO DEFINE ZONES WITH UNIQUE TEMPORAL SEQUENCES

WITHIN AGRICULTURAL ZONE LABELING LOGIC AND PROPORTION ESTIMATION

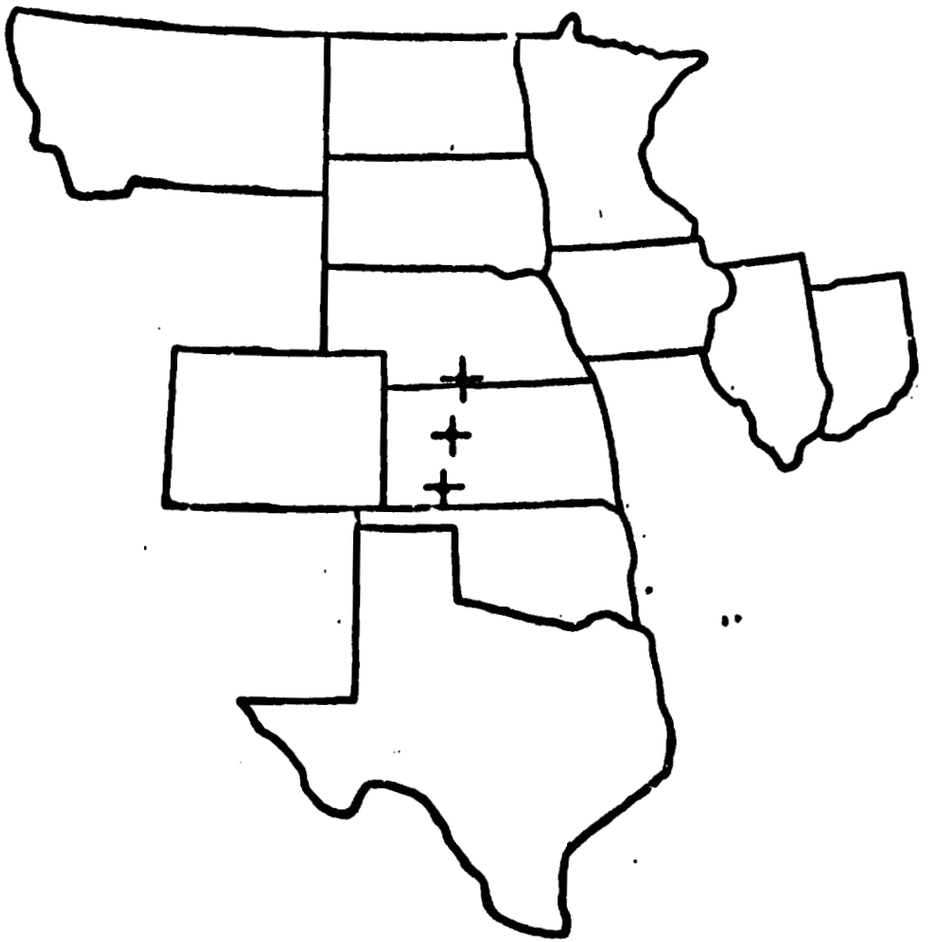
- HUE OR COLOR SEQUENCE FROM ACQUISITION TO ACQUISITION IS USED TO PROPORTIONALLY LABEL (BY CROP GROUP) EACH AGRICULTURAL ZONE.

CROP GROUP	COLOR SEQUNCE (1ST ACQUISITION/2ND ACQUISITION)	PROPORTION ESTIMATION
WINTER	RED/NOT RED	RED PIXELS IN ZONES LABELED WINTER + RED PIXELS ON THE FIRST ACQUISITION IN AREAS LABELED FALLOW
SUMMER	NOT RED/RED	RED AND ORANGE PIXELS IN AREAS LABELED SUMMER + RED AND ORANGE PIXELS ON THE SECOND ACQUISITION IN AREAS LABELED FALLOW
FALLOW	NOT RED/NOT RED	REMAINING PIXELS IN FALLOW
NATURAL VEGETATION	RED/RED	ALL PIXELS IN ZONES LABELED NATURAL VEGETATION
PASTURE		ALL REMAINING PIXELS

FEASIBILITY TEST

- TEST AREA
  - PORTIONS OF 3 SCENES IN WESTERN KANSAS (PATH 32, ROWS 32, 33, AND 34), MAY 30 AND AUGUST 1, 1980
- STANDARD FOR COMPARISON
  - PROPORTIONATE ALLOCATION (BY AREA) OF COUNTY LEVEL CROP ACREAGE STATISTICS TO SCENE PROCESSING UNITS (ASSUMPTION: UNIFORM DISTRIBUTION OF CROPS WITHIN A COUNTY)

FEASIBILITY TEST SCENE LOCATIONS



ESTIMATE ERROR

LUPE WHEAT PROPORTION
ESTIMATE ERROR

MEAN ERROR = -0.90
σ = 5.84
n = 18

MEAN WHEAT ESTIMATE (%) = 20.5
MEAN WHEAT GROUND TRUTH (%) = 21.4

LUPE SUMMER CROP PROPORTION
ESTIMATE ERROR

MEAN ERROR = 2.26
σ = 5.06
n = 18

MEAN SUMMER CROP ESTIMATE (%) = 17.56
MEAN SUMMER CROP GROUND TRUTH (%) = 15.30

n IS THE NUMBER OF
30 BY 30 NAUTICAL MILE
FULL FRAME SECTIONS
PROCESSED

LACIE PHASE III WHEAT PROPORTION ESTIMATES BY SEGMENT

SEGMENT NUMBER	COUNTY, STATE	WINTER WHEAT ESTIMATE (%)	WINTER WHEAT GROUND TRUTH (%)
1155	PHILLIPS, KS	21.0	22.7
1220	HARPER, OK	23,8	21.3
1290	FORD, KS	30.2	43.0
1293	MEADE, KS	10.5	14.8
1295	OSBORNE, KS	29.2	42.5
1355	BEAVER, OK	25.0	12.8
1479	HARLAN, NB	6.7	17.7
1588	WEBSTER, NB	20.6	21.6
1851	GRAHAM, KS	23.4	22.3
1853	NESS, KS	25.9	30.5
1890	PAWNEE, KS	33.8	38.9

OVERALL WINTER WHEAT RESULTS

MEAN ERROR = -3.45

σ = 7.46

n = 11

MEAN WINTER WHEAT ESTIMATE (%) = 22.7

MEAN WINTER WHEAT GROUND TRUTH (%) = 26.2

CROP PROPORTION ESTIMATES BY SCENE BY SECTION

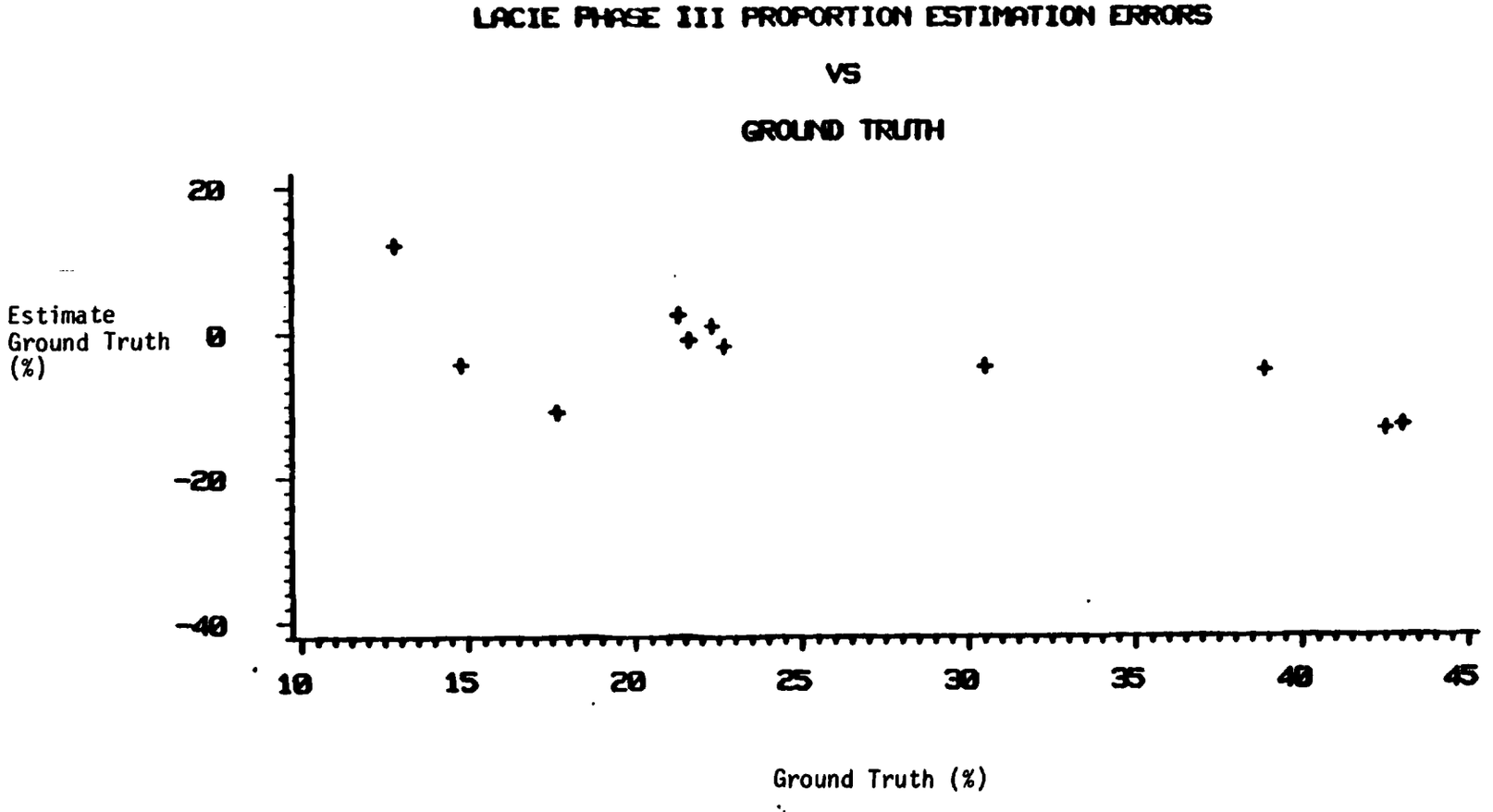
PATH/ ROW	SECTION	WINTER GRAINS ESTIMATES (%)	WINTER GRAINS GROUND TRUTH (%)	SUMMER CROP ESTIMATES (%)	SUMMER CROP GROUND TRUTH (%)
32/32	4	19.97	5.7	51.04	51.6
	5	23.61	11.6	30.46	32.7
	6	20.62	19.9	13.35	8.9
	7	12.36	11.5	41.96	53.1
	8	24.83	13.3	17.37	23.9
	9	28.29	22.1	15.01	12.6
32/33	4	21.57	22.6	7.15	6.5
	5	21.52	23.6	7.41	5.9
	6	20.61	25.8	10.64	4.4
	7	17.43	23.0	11.56	6.3
	8	25.90	29.2	12.72	5.1
	9	28.06	33.3	12.79	9.3
32/34	4	27.06	29.7	16.72	15.4
	5	25.01	23.4	13.24	14.7
	6	3.19	24.0	8.32	8.3
	7	27.90	27.5	16.96	11.4
	8	8.51	15.7	15.36	3.1
	9	10.71	23.5	13.81	2.0

OVERALL WINTER GRAINS RESULTS
MEAN ERROR = -0.90
σ = 5.84
n = 18

MEAN WINTER GRAIN ESTIMATE (%) = 20.5
MEAN WINTER GRAIN GROUND TRUTH (%) = 21.4

OVERALL SUMMER CROP RESULTS
MEAN ERROR = +2.26
σ = 5.06
n = 18

MEAN SUMMER CROP ESTIMATE (%) = 17.56
MEAN SUMMER CROP GROUND TRUTH (%) = 15.3

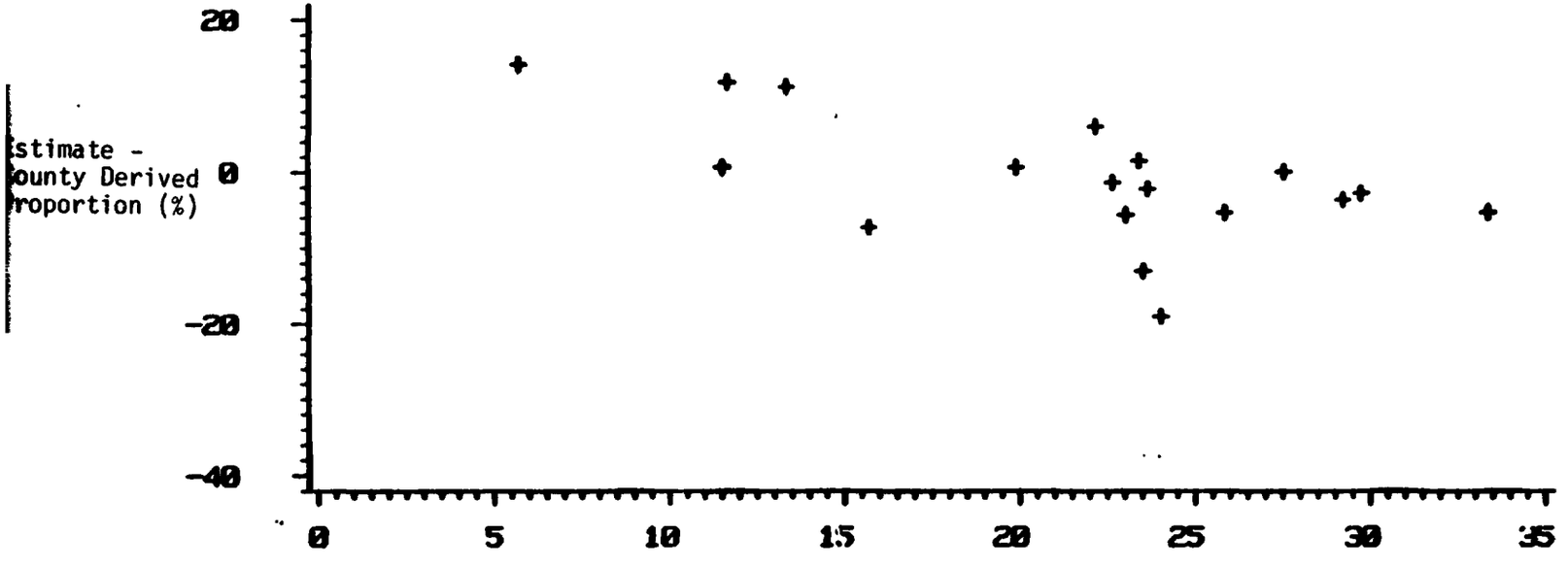


LARGE UNIT PROPORTION ESTIMATOR

WINTER WHEAT PROPORTION ESTIMATION ERRORS

VS

COUNTY DERIVED PROPORTIONS

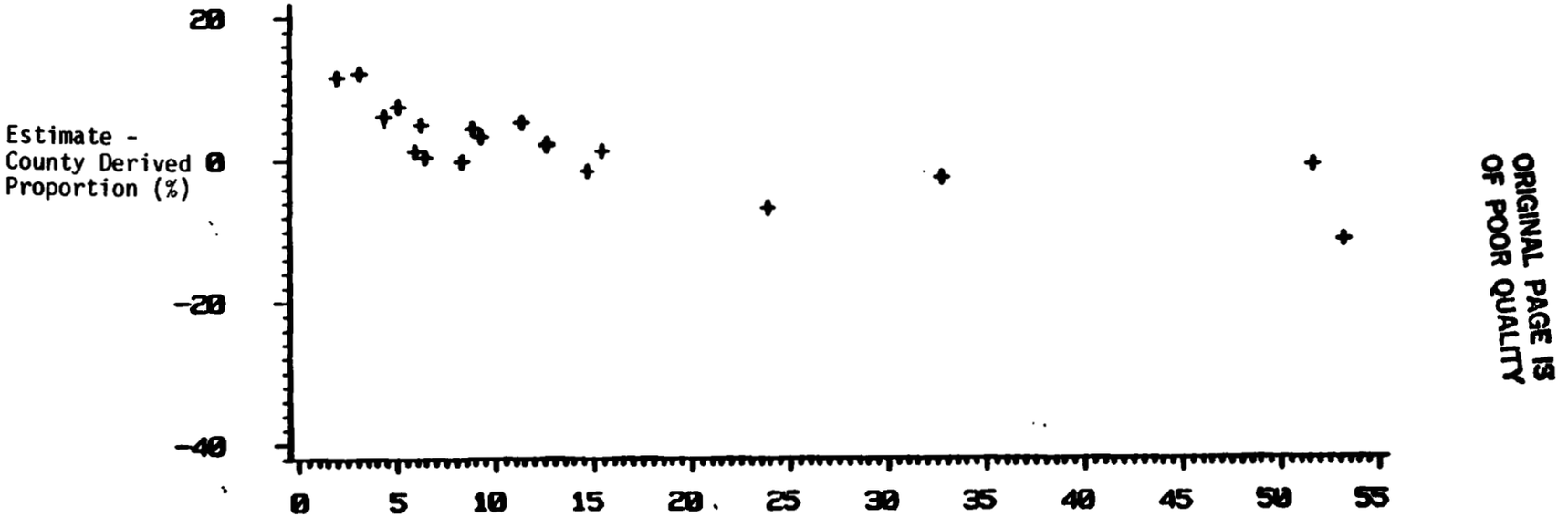


LARGE UNIT PROPORTION ESTIMATOR

CORN + SORGHUM PROPORTION ESTIMATION ERRORS

VS

COUNTY DERIVED PROPORTIONS



CONCLUSIONS AND REMARKS

- O APPROACH DEVELOPED WITH DESIRABLE ATTRIBUTES
  - + PRECISE REGISTRATION NOT REQUIRED
  - + USES SKIP SAMPLED FULL-FRAME DATA
- O ACCURACY RESULTS PROMISING FROM INITIAL TEST
  - + ADDITIONAL TESTING PLANNED
- O APPROACH IS EFFICIENT
  - + SCENE PROCESSING FROM BEGINNING TO END (REGISTRATION, DATA SCREENING AND TRANSFORMATION, PROPORTION ESTIMATION AND MAPPING) REQUIRES LESS THAN 3 HOURS TECHNICIAN TIME AND JUST OVER 1 HOUR CPU TIME
- O OTHER POTENTIAL BENEFITS
  - + APPLICABLE TO SMALL FIELDS REGIONS
  - + MAPPING ORIENTED
  - + PROVIDES A MORE DETAILED CLASSIFICATION OF AGRICULTURAL LAND THAN DOES THE USGS ANDERSON LEVEL II

DEVELOPMENT OF COMMON FEATURES FOR MULTI-SATELLITE AGRICULTURAL INFORMATION EXTRACTION

Richard C. Cicone

Objectives

- Develop Techniques that Take Advantage of the Joint Capabilities of a Multisensor Configuration for Agricultural Information Extraction
    - + MSS and TM spatial/spectral attributes
    - + AVHRR temporal attributes
    - + CZCS temporal/spectral attributes
- As an Initial Step, Develop Common Features Among Sensors that are Related to Agricultural Factors by Intercalibrating Their Spectral Response*

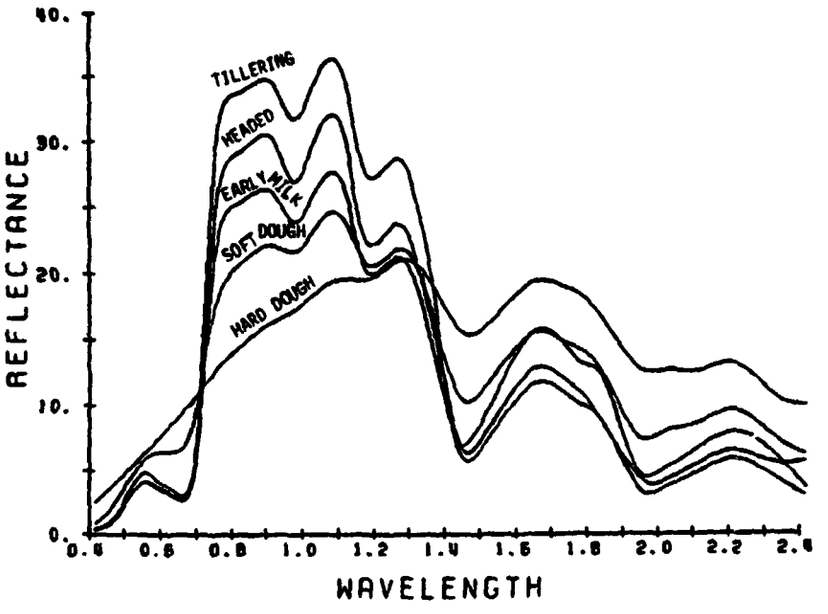
*Comment: With the advantage of building upon the existing knowledge base due to EW/CCA and FCCAD

Approach

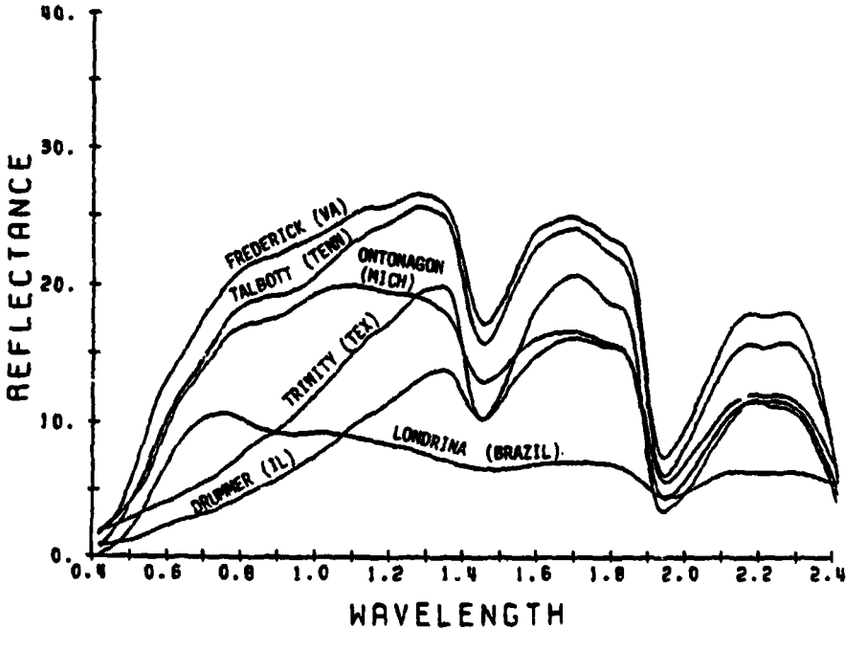
- Compare and Constrast Sensor Spectral Features
    - + Simulate signals observed by each sensor through a clear atmosphere for key agricultural crops
    - + Compare dispersion of sensor's signal in spectral space using 'Tasseled Cap' based analysis
    - + Examine relationship of like features
- Determine Techniques for Sensors' Joint Use
    - + Intercalibration coefficients
    - + Agricultural information extraction methods

SIMULATION DATA BASE

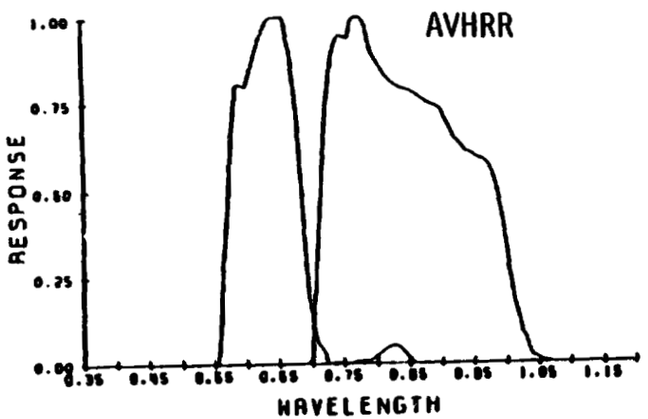
AVERAGED WHEAT SPECTRA

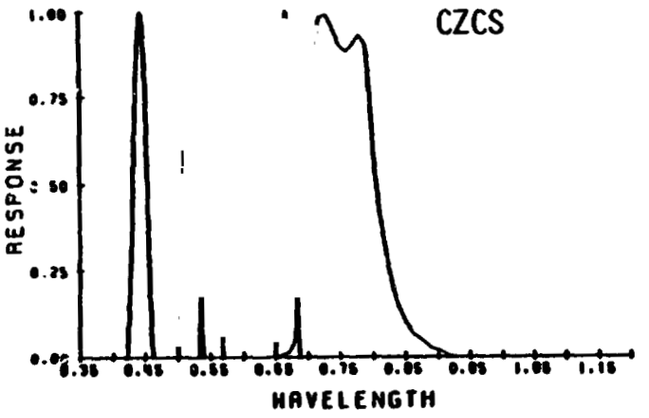


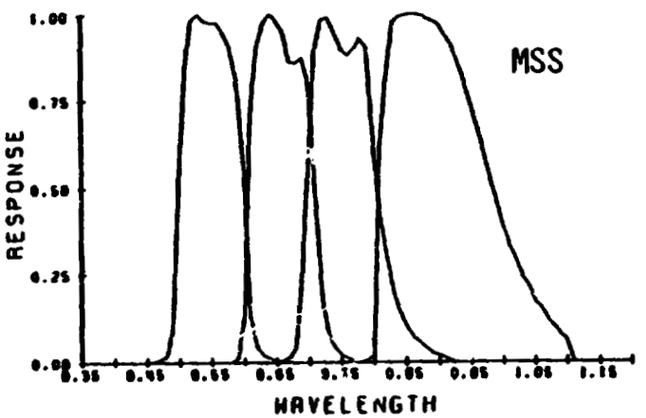
CHARACTERISTIC SOIL SPECTRA



SENSOR SPECTRAL RESPONSE FUNCTIONS







NOAA AVHRR utilizes a visible band located in the green-red portion of the spectrum and a near-IR band. Nimbus CZCS utilizes 5 narrower bands in the visible/IR region. The fifth band is identical to Landsat MSS band 6. Landsat MSS utilizes two visible and two near-IR bands.

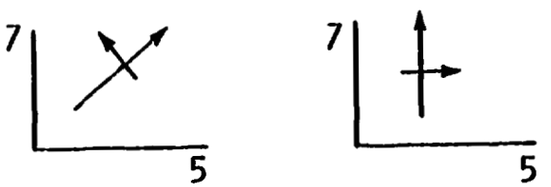
SENSOR CHARACTERISTICS

	AVHRR		CZCS	MSS		
	NOAA 6	NOAA 7	NIMBUS 7	Landsat 1-3	Landsat 4	TM
# Visible/Near-Mid-IR Bands	2	2	5	4	4	6
Orbit Altitude	850 km	850 km	955 km	920 km	705 km	705 km
Equator Crossing	7:30 ↓	14:30 ↑	12:00 ↑	9:30 ↓	9:30 ↓	9:30 ↓
Nadi. Ground Resolution	1100 m	1100 m	825 m	79 m	83 m	30 m
Swath Width	2250 km	2250 km	1566 km	185 km	185 km	185 km
Field of View	$\pm 56^0$	$\pm 56^0$	$\pm 39^0$	$\pm 5.5^0$	$\pm 7^0$	$\pm 7^0$
Repeat Coverage*	1/2 day	1/2 day	6 days	18 days	16 days	16 days

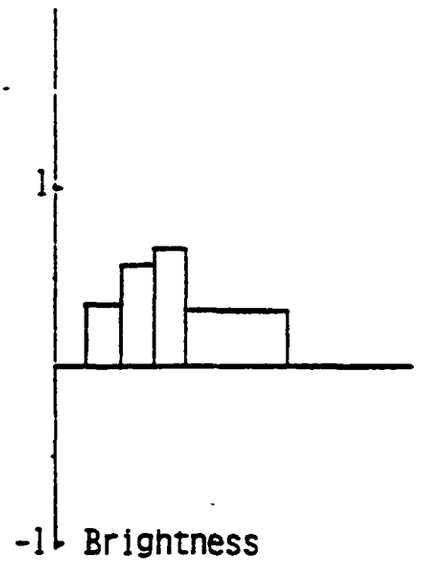
*AVHRR repeat coverage may be at wide view angle differences.

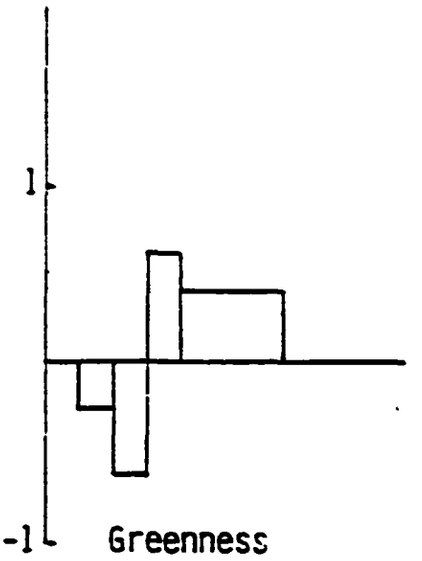
FEATURES OF TASSELED-CAP TRANSFORMATION

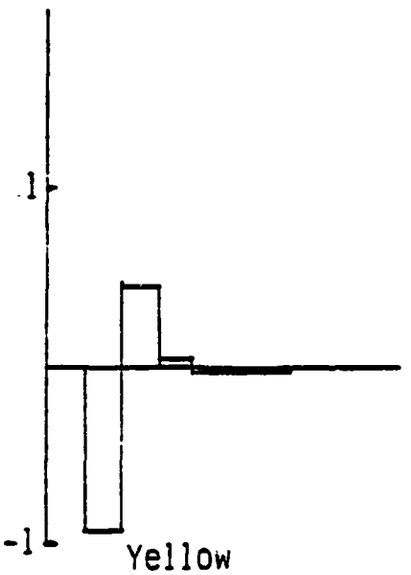
- A Linear Transform of Landsat MSS Band Values
- Developed for Agricultural and Forested Scenes
- 95% to 98% of the Variation in Landsat MSS Spectral Data is Described by Brightness and Greenness:
  - All bands contribute
  - Dimensionality reduction is possible with little loss of information
- Soil Variation Effects on Greenness are Minimal
- The Tasseled-Cap Transform has Advantages Over Conventional Principal Component Analyses Because:
  - Its directions are based on physical properties, remain fixed, and have consistent interpretability
  - Conventional principal component analyses depend on the composition of the data set being analyzed, e.g.,

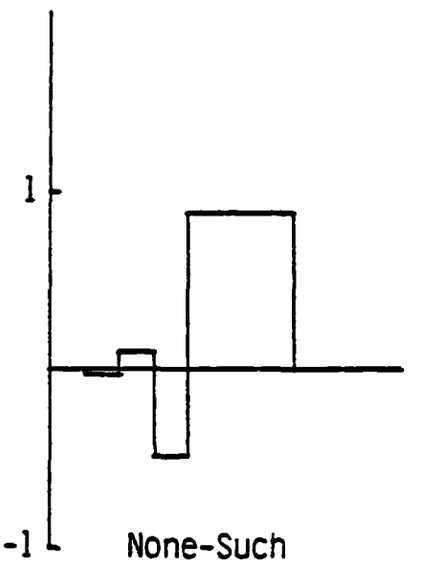


TASSELED CAP TRANSFORM

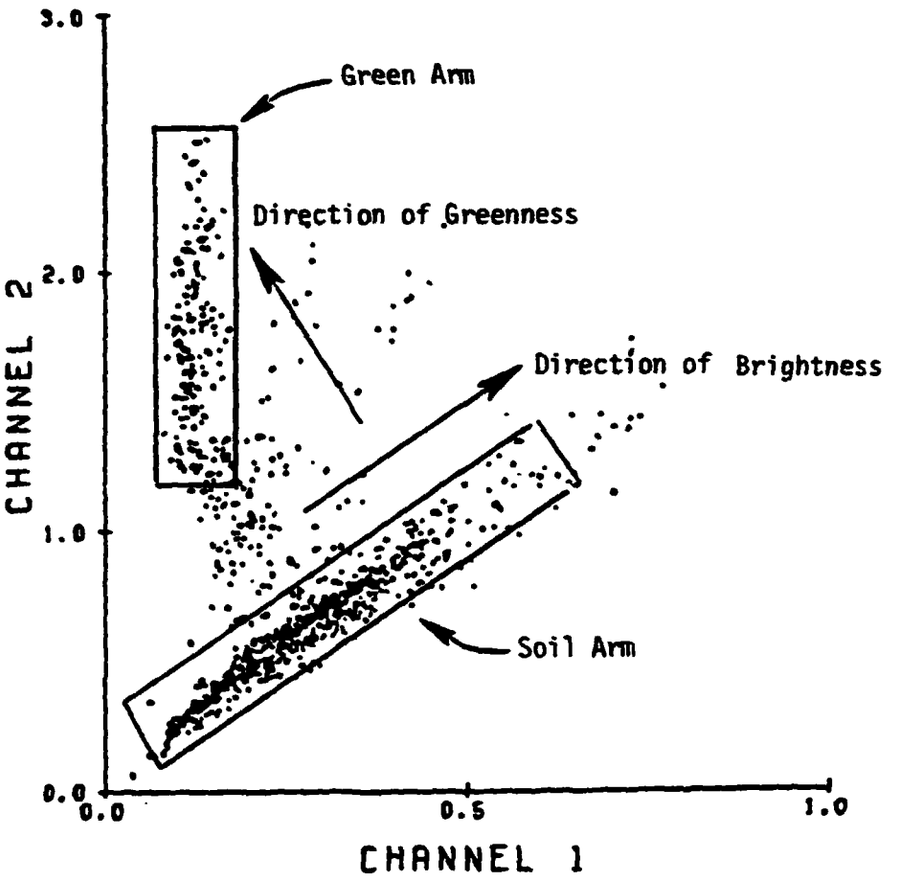






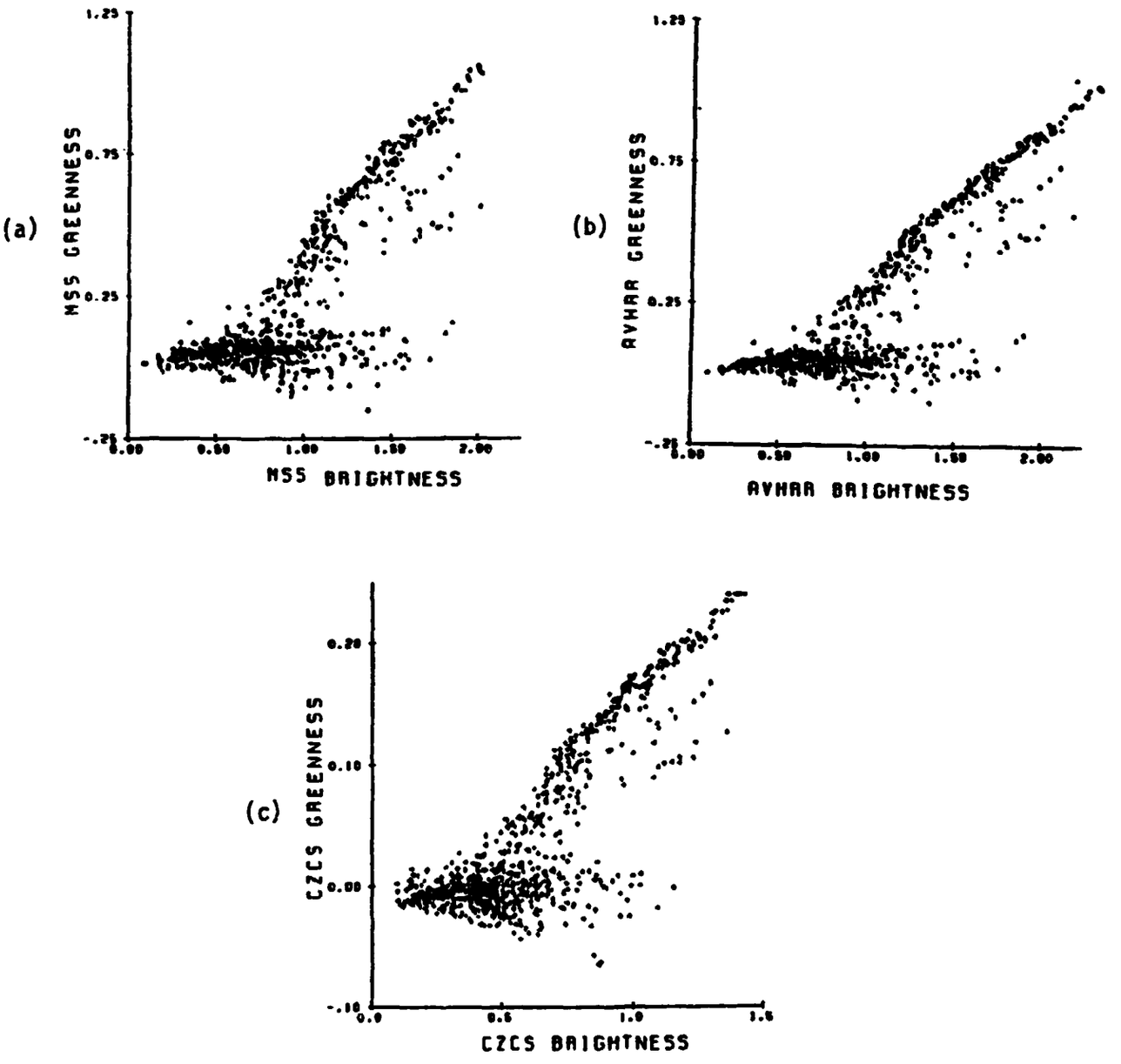


AVHRR TASSELED CAP ANALYSIS



The Green Arm and Soil Arm portions of AVHRR response are delineated. Tasseled Cap Greenness and Brightness are identified. Note that Greenness is not parallel to the direction of principle variation in the Green Arm.

COMPARISON OF KEY SPECTRAL FEATURES



GREENNESS VS. BRIGHTNESS OF MSS (a), AVHRR (b), and CZCS (c) shows the comparability of the data structures among sensors. Note that the variation in the Greenness direction of the Soil Arm increases with increased spectral resolution.

PERCENT VARIATION EXPLAINED BY PRINCIPLE COMPONENTS

		1st	2nd	3rd	4th
MSS	Soil	95.91(B)	3.02(G)	1.03	0.04
	Vegetation	59.62(G)	38.60(B)	0.67	0.10
AVHRR	Soil	98.40(B)	1.60(G)		
	Vegetation	68.80(G)	31.20(G)		
CZCS	Soil	92.45(B)	6.59(G)	0.71	0.15
	Vegetation	69.51(G)	28.39	1.69	0.41

INHERENT RADIANCE GREENNESS/BRIGHTNESS TRANSFORMS

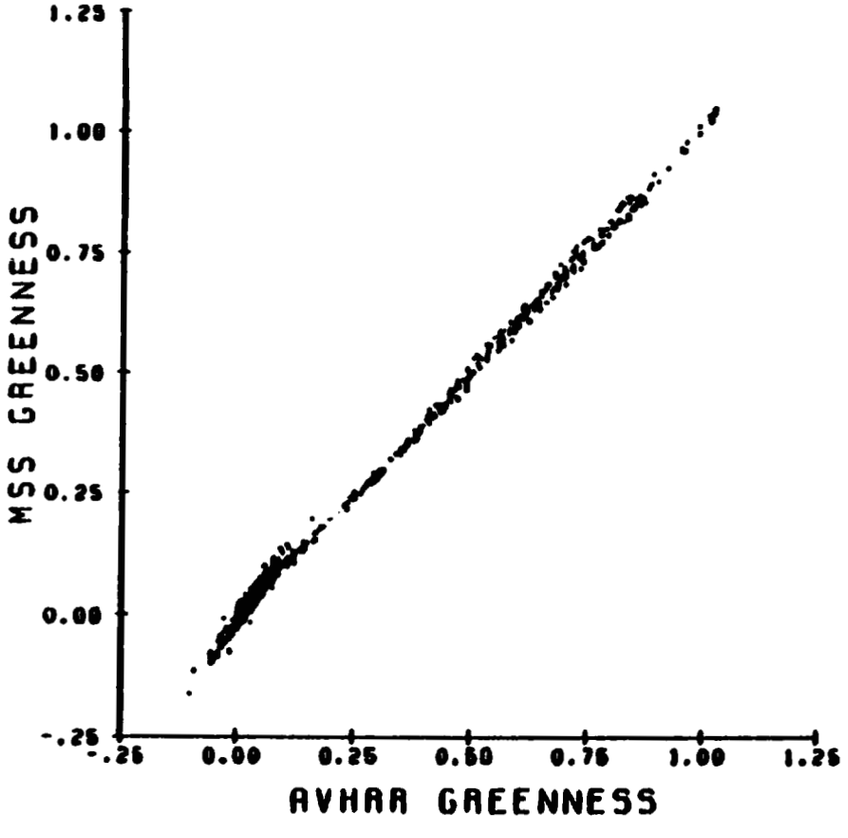
		C1	C2	C3	C4	C5
MSS	G	-.56	-.59	.13	.56	--
	B	.31	.45	.52	.66	--
AVHRR	G	.89	-.45	--	--	--
	B	.45	.89	--	--	--
CZCS	G	--	-.56	-.55	-.58	.21
	B	--	.09	.11	.17	.98

LINEAR RELATIONSHIP BETWEEN MSS FUNCTIONS
AND AVHRR,CZCS FEATURES (R^2)

	AVHRR	CZCS
Brightness	.996	.996
Greenness	.998	.989

RELATIONSHIP BETWEEN MSS GREENNESS AND AVHRR GREENNESS

(R^2 > .99)



CONCLUSIONS

- Highly Correlated Features Corresponding to Vegetative Biomass and Target Albedo can be Derived from MSS, CZCS and AVHRR Space-Borne Sensors
- Have Developed a Methodology to Intercalibrate These Greenness and Brightness Features Among Sensors
- AVHRR Minimizes Variations of Soils in Greenness and Therefore may be More Sensitive to Detection of Emergence
- Need to Establish Practical Intercalibration Coefficients and Develop Methods for Joint Use of the Sensors so as to Exploit Particular Advantages of Each

INVENTORY TECHNOLOGY DEVELOPMENT (ITD)

PROJECT DOCUMENTATION

This listing includes only those documents published between April 1, 1982 and September 30, 1982.

INVENTORY TECHNOLOGY DEVELOPMENT

IT-E2-04233 "Augmentation of Landsat MSS Data by SEASAT-SAR for Agricultural Application" (April 1982)

IT-J2-04262 "Presentation of Information of the Inventory Technology Development Quarterly Technical Interchange Meeting, March 24-25, 1982" (April 1982)

IT-J2-04267 "Semi-Annual Program Review Presentation to Level 1, Interagency Coordination Committee" (April 19, 1982)

IT-J2-04282 "Research in Satellite-Aided Crop Inventory and Monitoring for LARS" (April 1982)

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